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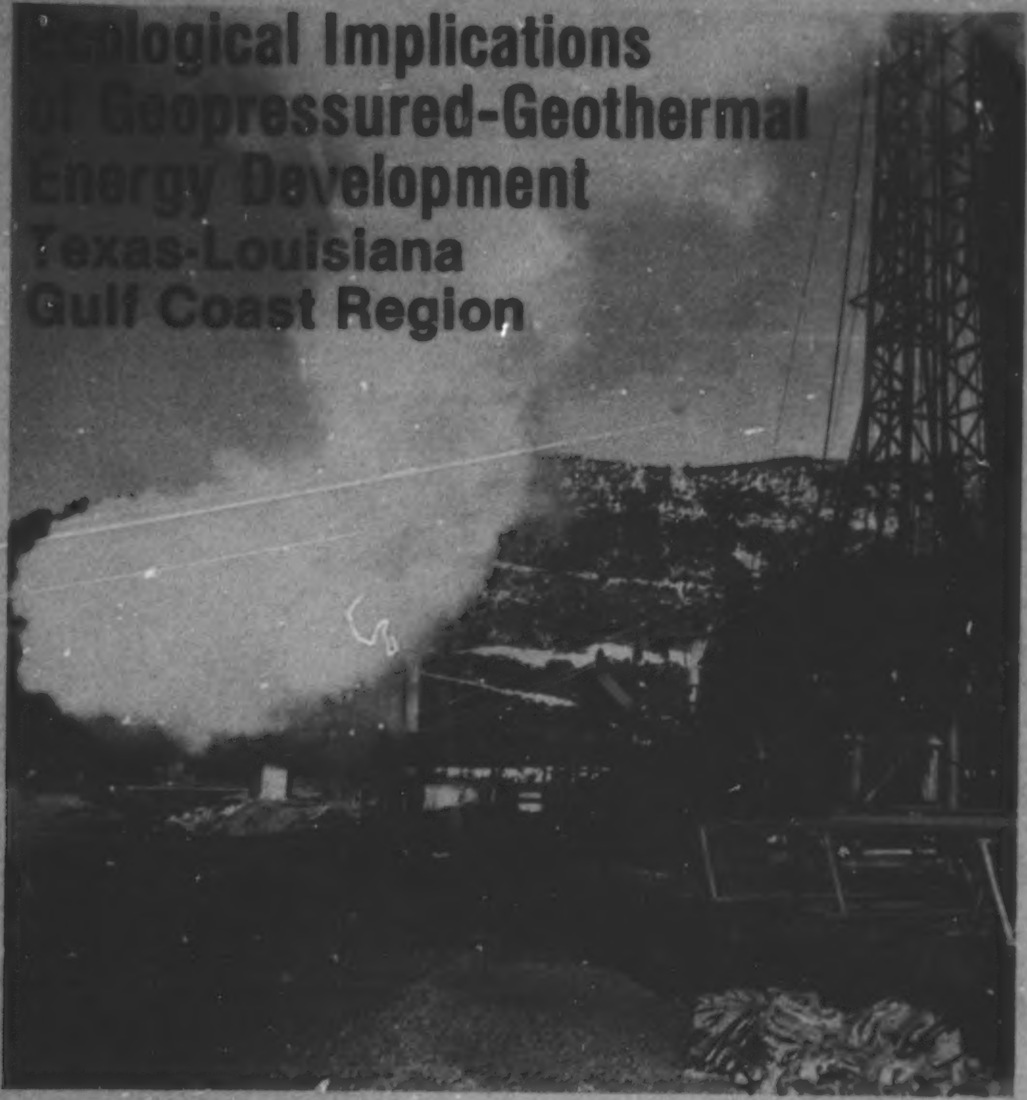

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This study contains two main sections, in which the ramifications of the commercial development of Thermal-Hydraulic Energy for the generation of electrical power are reviewed from the different perspectives of the area as an Energy Resource and as an Ecological Resource. This includes an extensive review of information regarding fish and wildlife, and the estimated impact from Geothermal development, in the study area; a review of Geothermal Energy Conversion Systems, contrasting them with alternate systems; and a listing of unique or endangered species within the region. The nature of this study , by considering Geothermal development implications from both the energy and the ecological resource perspectives, make it valuable to a broad range of people concerned with controlling the potential ecological impacts of development within the region.

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EXECUTIVE SUMMARY

Geopressured-geothermal resources of the Texas and Louisiana Gulf Coast are currently being evaluated as the thermal-hydraulic energy sources for generation of electric power. Concurrent studies are underway to determine the environmental effects of development of these resources. The most significant environmental concerns are subsidence resulting from the withdrawal of enormous volumes of formation waters and the disposal of highly saline brines.

Analyses of fluids from the geopressured zones of both Texas and Louisiana indicate that TDS values from less than 20,000 ppm to as much as 345,000 ppm may be expected.

For geopressured fluids Na^+, Cl^-, Ca^{++}, HCO^{3-}, B^{+++} ions have been recorded in concentrations of up to 1 order of magnitude greater than sea water with Ca^{++} ion concentrations sometimes an order of magnitude less than sea water. K^+ and Br^- ion concentrations bracket their concentrations in sea water and occur in concentrations as much as one half order of magnitude more or less than their normal sea water concentrations. The normal concentration of SO_4^{--} ions in sea water is nearly 2450 ppm. In geopressured fluids concentrations may be two orders of magnitude less; several analyses indicate that SO_4^{--} ions are missing altogether.

Data on trace elements in geopressured fluids is very limited although Gustavson and Kreitler report beryllium, copper, iron, and strontium in formation fluids from the Chapman Ranch Field south of Corpus Christi. Kharaka and others (1977) report traces of sulfate ion, hydrogen sulphide, rubidium and ammonia from the Chocolate Bayou Field in Texas.

Geopressured fluids are not concentrated sea water with a regular and systematic increase in all dissolved ions, but are complex solutions that are in part the result of fluid and ion migration and chemical reactions that accompany the burial of sediment and its subsequent diagenesis. Therefore, in the event that geopressured fluids are released into bays, lagoons, or the Gulf of Mexico the fluid release cannot be simply equated to an input of concentrated sea water, for the balance of ions in geopressured fluids differs markedly from the ionic balance of normal sea water.

The commercial development of geothermal resources can be described in terms of three location scenarios:

(1) The first scenario places production generating and disposal facilities on coastal lowlands or uplands where access will be available by roads. The power plant will occupy a relatively small area within a network of production wells, and spent fluids will be disposed via reinjection wells. In this scenario a minimum of land area would be impacted directly as well site, pipelines and access roads to the well sites, storage ponds and generating plant site.

(2) The second scenario places generating production and disposal facilities on low lying coastal marsh lands that occur primarily in Louisiana. Under these circumstances production and disposal-well sites would be accessible primarily by dredged canal. The generating plant would be placed on a pad of made land constructed from dredge spoil. Access to the generating facility would require dredging either a canal or dredging of material to support a road. Substantial dredging would be required to open canals to more heavy equipment to and from drill sites and the generating facility and to construct and maintain pipelines.

(3) The third scenario requires that production facilities be located offshore in estuaries, bays, lagoons, coastal lakes or the Gulf of Mexico. Under these circumstances production facilities may consist of a network of wells in the water body or of groups of directionally drilled wells that may be serviced from one or two productions platforms. In this case a gathering facility and the array of injection wells would be located on land and connected to the production platforms by pipeline.

Of the three scenarios development on coastal lowland would result in the least impact to the environment while development in coastal marshlands would result in severe environmental impacts.

For each location scenario, two possible power plant systems may apply; two-stage flashed steam and binary cycle systems. Approximately 10 to 12 production wells at a flow rate of 6,560 m^3/day (40,000 bbl/day) would be required to supply geothermal fluids to a 25 megawatt flash plant; and 20 to 24 injection wells with injection rates of 985 m^3/day (6,000 bbl/day) would be required to dispose of the spent geothermal fluids for a facility of this magnitude. At 1/2 mile spacings the well fields would require seven to ten square miles. The plant site would require approximately 10 acres with additional acreage being required possibly for temporary holding ponds or tanks.

The fundamental difference between the flash method and binary (secondary working fluid) method in terms of environmental impact is that the flash method allows noncondensable gases to be passed to the atmosphere, or flared if combustible.

A system of pipelines to collect and carry geothermal fluids from production wells to the power plant site and later to the disposal facilities will be necessary. Current practice on land is to bury pipelines. The environmental impact of burying a pipeline on land is relatively minor, consisting of disturbed soil and vegetation along the route of the pipeline. Vegetation can be reestablished generally along the pipeline within a few months. The construction of pipelines or canals through wetlands, bays, estuaries, or the Gulf of Mexico, however, is likely to result in significant local environmental impacts. Major impacts will result from loss of habitat and vegetation in areas occupied by spoil piles, levees and canals. Reduction of water quality will probably result from the redistribution of heavy metals, pesticides, sulfides and particulate matter contained in the dredged spoil. Canals and levees serve to interrupt natural drainage of marsh areas and can locally raise or lower water levels.

Geothermal fluids could be disposed of into surface water bodies or they could be injected into the subsurface. Disposal into surface waters would be by pipeline exposed near the bottom of a water body and fitted with a device to cause rapid and effective mixing with ambient waters. Disposal of large volumes of brine into surface waters or temporary storage in holding ponds is however, likely to result in significant environmental impacts. Gustavson and Kreitler (1976) describe the impact to Chiltipin Creek of salts that are apparently the residual of evaporated oil field brines. Salinity of Chiltipin Creek waters have exceeded 35,000 ppm several times a year since 1969 effectively destroying the natural environments of the stream. The numerous potential problems associated with surface disposal include: (1) total quantity of fluids produced daily, (2) salinity of fluids and protection of potable water supplies, (3) noxious or poisonous gas removal or conversion, (4) thermal content of fluids and thermal enrichment to environment near point of disposal, (5) entrained and dissolved solids removal before fluid disposal, (6) creation of appropriate fluid mixing zones to eliminate stratification and other effects in the recipient water body, (7) maximum salinity and temperature deviations from natural salinity and temperature environment of receiving water body, (8) impact of pipeline construction on the environment.

Disposal of geothermal fluids into the subsurface will result in substantially less impact to the environment than would surface disposal. As much as twenty or more injection wells may be needed to dispose of the 64,800 m^3 (400,000 bbl) of spent fluid from a single 25 megawatt power-plant: the number of wells is dependent upon the rate of disposal per well. In the absence of an accidental release of brines, the only major impact resulting from the reinjection of geothermal brines would be possible upward migration of the base of fresh ground water that would overlie the area of the disposal field, or perhaps leakage of brines along faults.

From the complex network of production wells, pipelines, power plant, and disposal wells that will comprise a geopressured-geothermal electrical generating plant an accidental release of hot brines is, at least remotely, possible. The times when this is most likely to happen is in the process of drilling the well--a blow out--during normal maintenance procedures of an operating well, or as a breech in the pipeline that will carry the geothermal water from production well to generators to disposal well.

Intense development will occur only at the power plant site where the construction of roads, temporary holding ponds, power transmission lines and the power plant will require the use of a minimum of 10 acres. The major impact here is that the area of the development site is withdrawn from the natural system. Disposal and production wells will be serviced by a network of unimproved dirt roads whose impact on upland area environments will be minor. The construction of roads or canals in wetland areas would, however, be a severe impact on the local environment.

The utilization of geopressured-geothermal resources requires the withdrawal of enormous volumes of geothermal fluids from the subsurface. It is probable that fluid withdrawal from aquifer sandstones in the geopressured system will allow fluids from adjacent mudstones to flow into the sandstone aquifers as a pressure gradient is established. This induced dewatering of geopressured mudstones will probably allow a certain amount of compaction of mudstones to take place, in conjunction with sandstone compaction. Transmittal of the compaction to the surface may result in subsidence. The impact of subsidence in undeveloped upland areas will probably be minor. Subsidence in or near wetlands could result in a significant environmental impact in that slight changes in land elevation can result in extensive lateral shifts in wetland vegetation zones, and extensive damage to the works of man.

Active faulting on the Gulf Coast has been recognized in several areas and, in part at least, fault planes may control or limit subsidence. This is not to say that the Gulf Coastal Plain of Texas and Louisiana is a seismically active area. Recent fault movement in the Gulf Coast has been documented, but the movement has apparently been too local and too slow to generate seismic shocks. Major impacts resulting from fault movement has been damage to structures such as pipelines, roads, buildings, and air fields.

The development of geopressured-geothermal resources under all three scenarios will result in similar elevated noise levels. Temporary noise level increases will result from the construction of each drill site and from well drilling. The drilling operation involving the use of heavy equipment and large diesel engines occurs 24-hours a day for several weeks or longer and noise levels of 80 to 90 dBA can be expected. The construction of pipelines and the power plant will also result in local temporarily increased noise levels largely due to the operation of construction equipment. The effects of elevated noise levels on animal life is not clearly understood, but does not appear to be of major significance.

Conversion of geothermal energy to electrical energy will yield waste products that will impact several sectors of the environment. Although only limited data is available on the chemical composition of produced geopressured-geothermal waters, general knowledge of concentrations and distributions of ions is available. Possible air contaminants derived from the release of geothermal fluids are water vapor, methane (CH_4), non-methane hydrocarbons (C_NH_N), hydrogen sulphide (H_2S), boric acid (H_2BO_4) and ammonia (NH_3). If extracted hydrocarbon residues are burned, other carbon compounds may be released to the atmosphere.

The impact of geothermal fluids depends on the manner in which they are disposed. In the marshlands and estuary systems of the coastal zone, a delicately balanced broad mixing gradation of fresh to salt water exists and direct disposal or accidental release into surface waters can have a number of significant negative impacts. Mixing occurs as fresh water discharge from streams intermingles with oceanic waters moving landward through tidal inlets and passes, and by storm inundation. The primary effects will be the degradation of vegetation and aquatic fauna intolerant to quick salinity or temperature changes resulting from geothermal fluid releases. In addition, boron or other toxic elements contained in geothermal waters may be sufficient to produce harmful effects to biota. Release of saline geothermal fluids on land would impact vegetation and temporarily increase soil salinity. Sustained releases on land could increase soil salinity to the point where the soil would no longer support vegetation.

Contamination of fresh ground water can occur in two fashions: contamination of shallow ground water from the release of geothermal fluids at the surface and contamination of deep ground water by intrusion or updip migration of saline ground water driven from disposal wells.

Many methods of condenser cooling are possible in the coastal region and each method employs treatments or induces some chemical and physical effects on the cooling waters. Chlorine may be added to prevent fouling of condensers by untreated natural water. Additional algicides, biocides and corrosion and scaling inhibitors are added to recirculating cooling systems and these chemicals can become concentrated by evaporation in draft towers or holding ponds. Furthermore these cooling fluid additives are carried into the atmosphere and to the surrounding landscape in water vapor droplets.

Operating thermal efficiencies in most types of generating facilities today is less than 50 percent. Most of the energy is lost or dissipated as low-grade waste heat additions into the environment. The discharge of heat to a body of water can cause various physical, biological and chemical effects. With increasing water temperature, the oxygen holding capacity of the water decreases; density changes may cause stratification; evaporation is increased; chemical, biological, and physical reaction rates increase; and viscosity decreases. Surface waters of the Texas-Louisiana coast cover a whole spectrum of different types of water bodies and water chemistries from open marine to fresh water pond, in arid to semi-tropical environments. If surface waters are used in a cooling system or for disposal of geothermal waters, effects of geothermal heat discharge will be dependent on plant site location and proximity to and use of water bodies.

A number of potential impacts to fish and wildlife resources are recognized based on information on ecosystems of the region and the potential nature of commercial exploitation of geothermal resources. Such impacts are evaluated in relation to the three possible location scenarios presented above.

Processes and fluctuations among physical, chemical, and biological ecosystem components are emphasized to provide a baseline that will enable the identification of critical requirements for maintaining ecosystem productivity and integrity. Environmental effects of extractive exploitation of geopressured resources may be localized if spent geothermal fluids are disposed of by deep well injection and if only a few small power plants can be supported by the source. The latter may be a valid assumption if current predictions of the extent of the exploitable resource are accurate. Major constraints on such exploitation may be environmental impacts that could result from land subsidence and surface disposal of brines, if injection is not possible. Other major constraints may be the limited extent of geological deposits suitable for exploitation and possible managerial problems. The constraints seem especially important when geopressured energy conversion systems are compared to solar, hydroelectric, cogeneration and tidal systems.

The exploitation of geopressured-geothermal resources will result in many of the problems associated with other types of geothermal deposits. These problems include industrial management for prevention of environmental damage, potential release of toxic substances from geothermal fluids (brine, ammonia, boron, and hydrogen sulfide), possible land subsidence, pipeline associated problems, electric power plant siting problems, transmission lines, solid wastes, organic pollutants, heat, and noise. Geopressured electrical generation activities may place demands on scarce water supplies.

An extensive, though not comprehensive review has been made of published and unpublished sources of information on fish and wildlife of the study area and on potential impacts resulting from exploitation of geopressured energy. The rationale for exploitation of geopressured resources has been reviewed in comparison with other potential energy conversion systems. The summary of ecological resources of the Gulf Coast includes human uses and natural ecological systems. The latter include marine, fresh water and terrestrial systems. These descriptions include both ecosystem process and biogeographical information. Considerable information is included on unique, rare or endangered species of the region. Included are lists of such plant and animal species and a bibliography on the ecology, distribution and behavior of vertebrate species of the area which are threatened with extinction.

Preliminary recommendations have been made with regard to siting of geopressured facilities. Areas that should be avoided include valuable fish and wildlife habitats. These include critical habitats for endangered species, as well as habitats essential to the life histories of species which are important economic resources of the area.

If technological problems could be solved, geopressured exploration in the open Gulf might be preferable to such activities in either terrestrial, fresh water or estuarine systems based on current knowledge. The latter systems appear to be much more sensitive to many of the types of stresses currently predicted for geopressured exploitation. Future knowledge of impacts which might result in the open Gulf may indicate that totally terrestrial siting may result in the most "controllable" system of the scenarios developed. Sites should be avoided which might result in damage to ground water supplies. Prairie sites should be preferred to forest or desert ones because restoration of vegetation of the latter sites by natural ecological succession requires a much longer time. Geothermal operations should be planned so that they do not interfere with essential behavior patterns of animals.

Of the proposed electrical conversion systems including flashed steam, total flow, and binary cycle, the latter appears to be most ecologically desirable because it does not require an outside source of water for cooling. The binary system is preferable to the flashed steam method because much of the cooling can be accomplished, although not all of it in the climate of the coastal zone, by air cooling towers. In addition this system does not allow noncondensable gases to be passed to the atmosphere. Consideration should be given to cogeneration systems that utilize spent geothermal fluids (low grade heat) as an energy source.

Because of the great differences between composition of geothermal brines and that of sea water, and because of the presence of toxic substances originating in either geothermal reservoirs or in the technology of the geothermal conversion systems, geothermal fluids, particularly liquids, should not be released to terrestrial or aquatic environments. Deep well injection may prove to be a solution, however there may be unknown impacts resulting from such disposal methods. Because facilities utilizing geothermal heat must be located near the geothermal field, very careful planning should be implemented to determine if the field and any associated structures, including industries and urban developments, will be compatible with other uses of the site and its surroundings, such as for wildlife or agriculture.

A number of research needs related to the problems addressed in this report have been summarized. An extensive reference section has been compiled and includes an annotated bibliography indexed by subject matter. Lists of research scientists and/or institutions with expertise on the Texas-Louisiana coastal zone and/or geothermal energy are included.

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PHASE I

ABSTRACT

This research program was initiated to provide an estimate of the potential environmental effects arising from the development of geopressured-geothermal resources on the Gulf Coast of Texas and Louisiana. This portion of the program describes the physical resource and provides an annotated bibliography.

The development of geopressured-geothermal resources along the Gulf Coast of Texas and Louisiana for generating electrical power is being initiated. Resource evaluations for Texas and Louisiana are largely completed and a single test well is planned for Brazoria County, Texas. It is expected that currently available drilling, production, pipeline, generating and disposal technology will be used to exploit the geopressured-geothermal energy resource. Potential environmental impacts arising from the development of geothermal energy on the Gulf Coast will vary with the location of the development site and with the type of generating and disposal systems employed.

Approximately 54,000 m^3 (310,000 bbl) of geothermal fluids per day will be required to feed a single 25 mw power plant. Produced waters are expected to be brines with temperatures in exeess of 149°C (300°F). The geothermal fluids are expected to be saturated with methane and may contain boron, ammonia and small amounts of hydrogen sulfide.

This report was submitted in partial fulfillment of Contract No. 14-16-0008-2141 by the Bureau of Economic Geology, The University of Texas at Austin. The study was conducted as part of the Federal Interagency Energy/Environmental Research and Development Program, U.S. Environmental Protection Agency, and was performed for the Western Energy and Land Use Team, Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior.

"Amid the fantastic hoopla over energy it becomes easy to overlook a simple fact. When the world needs heat more than its people need money, the missing techniques for the application of useful terrestrial heat will flourish and be accepted everywhere."

Edward F. Wehlage

INTRODUCTION

The United States is experiencing an ever increasing demand for energy at the same time that production of our domestic energy resources--primarily crude oil and natural gas--are declining. Increased energy demands, declining reserves and increasing prices for hydrocarbon fuels require that alternative energy sources, including geothermal energy, be examined. Furthermore, increased prices for intrastate natural gas and crude oil have in effect narrowed the competitive price gap between oil and gas and other energy sources such as geothermal energy.

Geothermal energy was first utilized on a commercial scale at Larderello, Italy where today electricity is generated from high pressured steam. Geothermal energy was also utilized in Iceland, Hungary, New Zealand and Mexico before electrical energy was generated from geothermal steam at the Geysers, California in 1960. Installed generating capacity in the United States for the conversion of geothermal energy to electrical energy is currently 908,000 kw and is entirely from the Geysers (Wehlage, 1976).

Worldwide, the currently operating geothermal areas are hydrothermal resources that were recognized by surface indications of a heat source at depth--hot springs or geysers or both. The area that is the subject of this report, the Gulf Coast of Texas and Louisiana, differs geologically from all of the currently producing areas in that Gulf Coast geothermal resources are not associated with cooling magmas, tectonism, or seismic events. The rock materials that contain the geothermal resources of the Gulf Coast differ from currently producing geothermal areas in that Gulf Coast rocks are exclusively sedimentary. Furthermore, the fluids that comprise the geothermal resources of the Texas and Louisiana Gulf Coast are geopressured.

PURPOSE

The following discussion provides an evaluation of the potential for development of geopressured-geothermal resources of the Gulf Coast of the United States and of the potential environmental intrusions that could occur as a result of development. For the purposes of this report the term Gulf Coast is meant to include both the marine and terrestrial areas adjacent to the coast lines of both Texas and Louisiana. The evaluation of their geopressured-geothermal resources will be based on discussions of (1) the physical and chemical properties of geothermal fluids (2) the distribution of geopressured sediments along the Gulf coast and (3) the availability of shallow sandstone reservoirs as disposal sites for spent geothermal fluid.

The currently recognized incentives for and constraints on the development of geopressured-geothermal resources are described. The kinds of production facilities, generating facilities, associated direct use industries, and disposal and storage facilities that are likely to be used are also documented. Potential environmental intrustions resulting from the exploration, production, and disposal of geothermal fluids will be discussed.

PROJECT DESCRIPTION

This study, which is funded by the U.S. Department of the Interior Fish and Wildlife Service, consists of two phases. The first phase describes the geopressured-geothermal energy resource of the Gulf Coast--the subject of this report--and the second phase describes the ecological resource of the Gulf Coast. Both phase I and phase II consist of reviews and analyses of published and unpublished information sources. Annotated selected bibliographies of pertinent sources are developed for both phases (Appendix F).

STUDY REGION DESCRIPTION

Areas of known geopressured sediments in Texas and Louisiana lie along the Gulf Coast or a few miles inland (figure 1). Bebout and others (1976, a and b, 1975) have defined geothermal fairways--areas where geothermal resources are most likely to occur--along the Texas Gulf Coast (figure 2). Hawkins (1976 and personal communication, 1977) has recognized several areas of interest in Louisiana, although the geology of the geopressured-geothermal resource there is less completely understood (figure 3).

The sediments that are most likely to contain geopressured-geothermal resources are within the Tertiary Frio, Vicksburg and Wilcox Formations andprobably occur largely within deltaic facies of those formations.

Geology

The outer Gulf Coastal Plain is composed of Quaternary sediments (figure 4a, b). These sediments are comprised of systems of fluvial sands and muds; delta distributary sands and interdistributary muds, primarily at the Mississippi River delta; strand plain sands and marshes from the Mississippi River delta westward to Galveston Bay; barrier island sands and

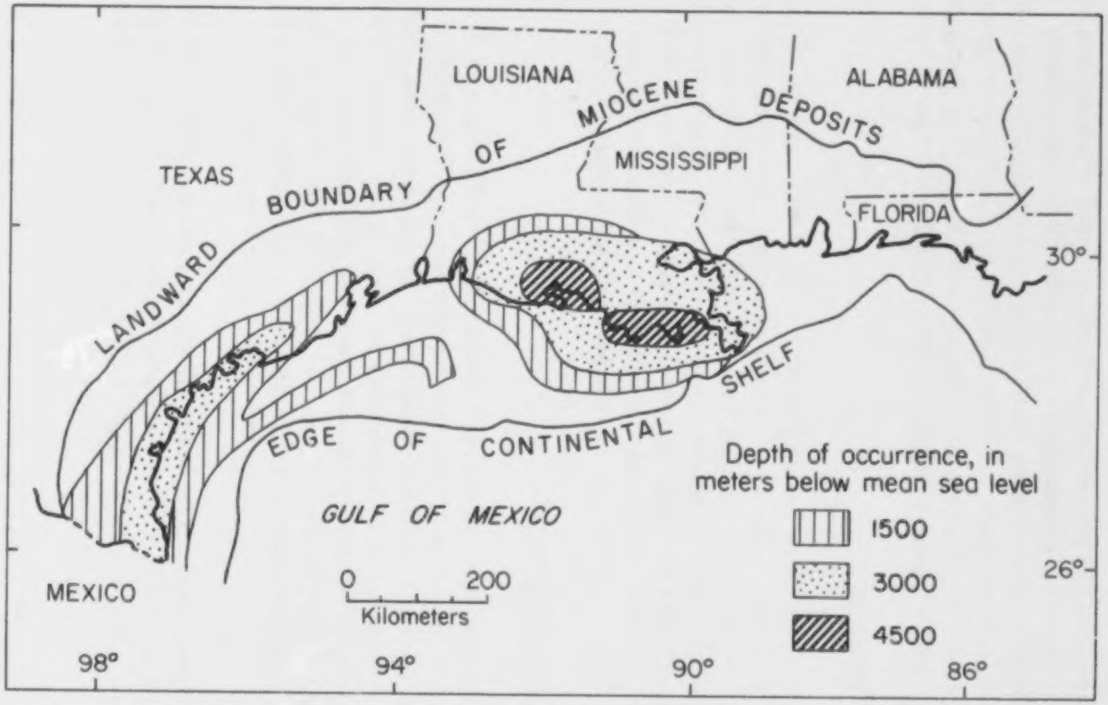

LOUISIANA
ALABAMA
TEXAS
MISSISSIPPI
FLORIDA
MEXICO
LANDWARD BOUNDARY OF MIOCENE DEPOSITS
EDGE OF CONTINENTAL SHELF
GULF OF MEXICO
0
200
Kilometers
Depth of occurrence, in meters below mean sea level
1500
3000
4500
98°
94°
90°
86°
30°
26°

Figure 1. Inferred extent of geopressured sediments in the Gulf Coastal region of Texas and Louisiana (from Jones, 1970).

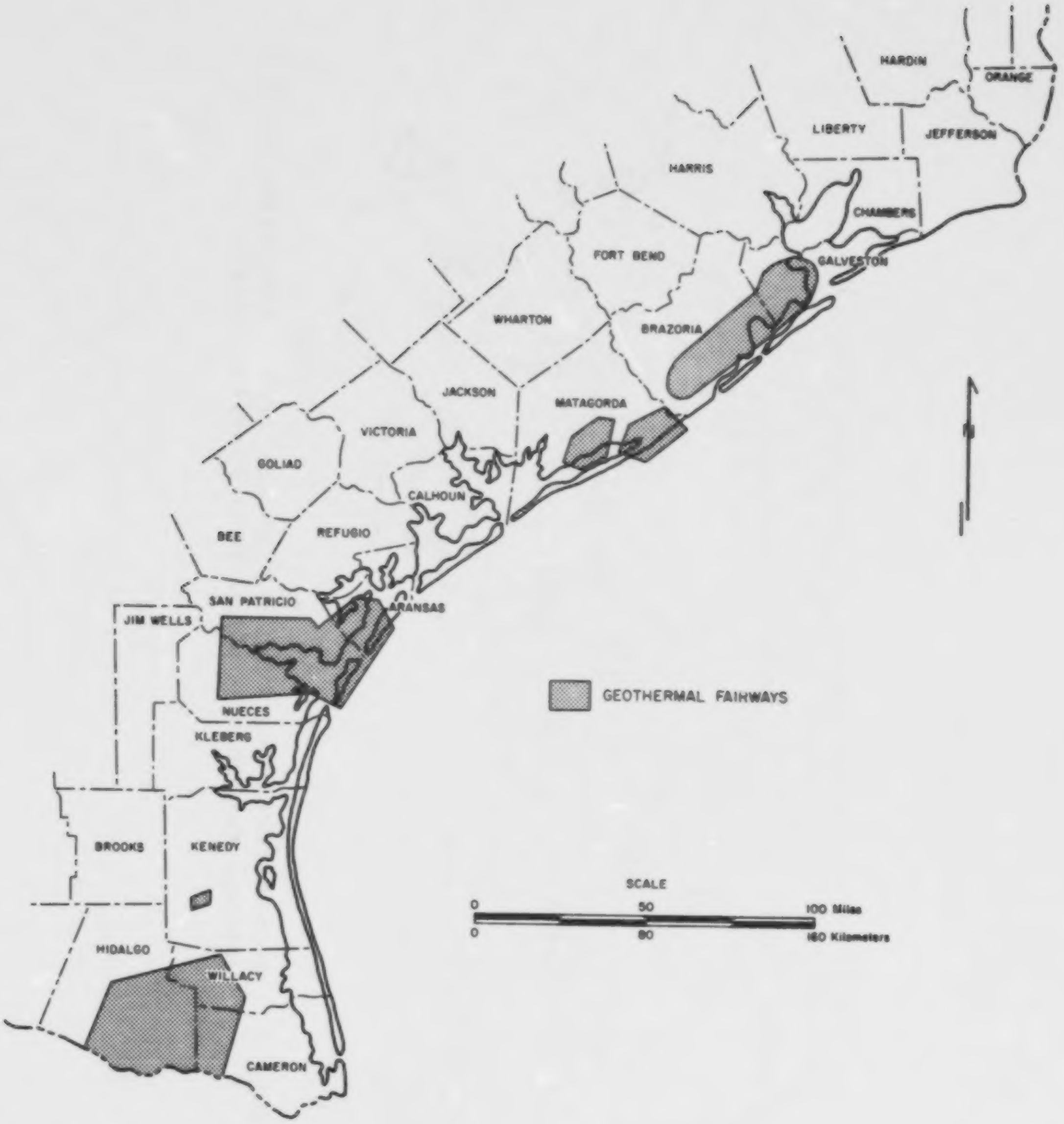

HARDIN
ORANGE
LIBERTY
JEFFERSON
HARRIS
CHAMBERS
FORT BEND
GALVESTON
WHARTON
BRAZORIA
JACKSON
MATAGORDA
VICTORIA
GOLIAD
CALHOUN
BEE
REFUGIO
SAN PATRICIO
JIM WELLS
ARANSAS
GEOTHERMAL FAIRWAYS
NUECES
KLEBERG
BROOKS
KENEDY
SCALE
0
50
100 Miles
0
80
160 Kilometers
HIDALGO
WILLACY
CAMERON

Figure 2. Geopressured-geothermal fairways, Texas Gulf Coastal region.

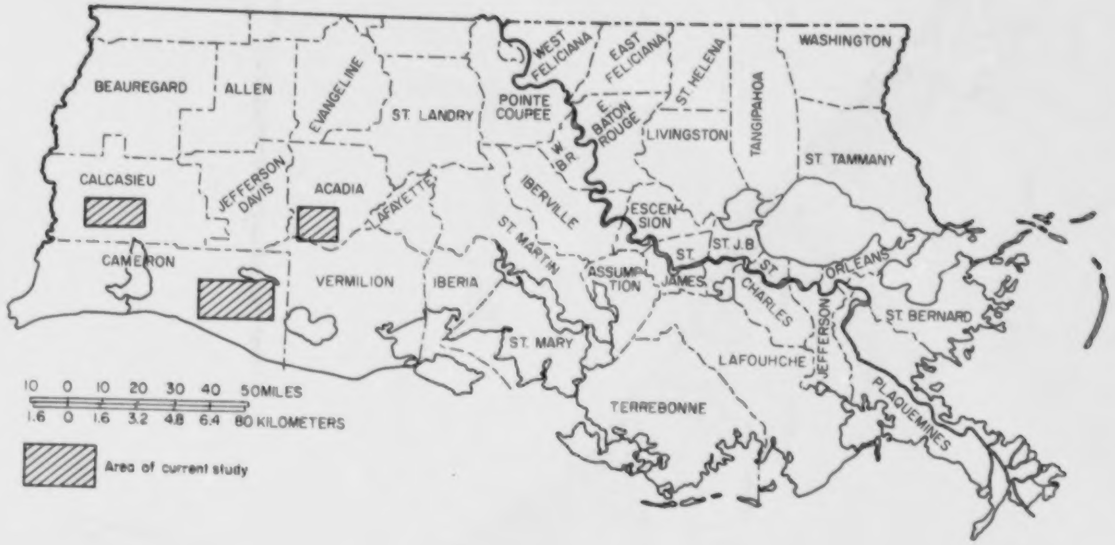

WASHINGTON
BEAUREGARD
ALLEN
EVANGELINE
ST. LANDRY
POINTE COUPEE
WEST FELICIANA
EAST FELICIANA
ST. HELENA
TANGIPAHOA
ST. TAMMANY
LIVINGSTON
E. BATON ROUGE
W. B.R.
CALCASIEU
JEFFERSON DAVIS
ACADIA
LAFAYETTE
IBERVILLE
ESCENSION
ST. J.B.
ST. MARTIN
ST. JAMES
ST. CHARLES
ORLEANS
CAMERON
VERMILION
IBERIA
ASSUMPTION
ST. BERNARD
JEFFERSON
LAFOUHCHE
ST. MARY
TERREBONNE
PLAQUEMINES
10 0 10 20 30 40 50 MILES
1.6 0 1.6 3.2 4.8 6.4 80 KILOMETERS
Area of current study

Figure 3. Geopressured-geothermal prospect areas, Louisiana Gulf Coastal region (modified from Hawkins, 1976).

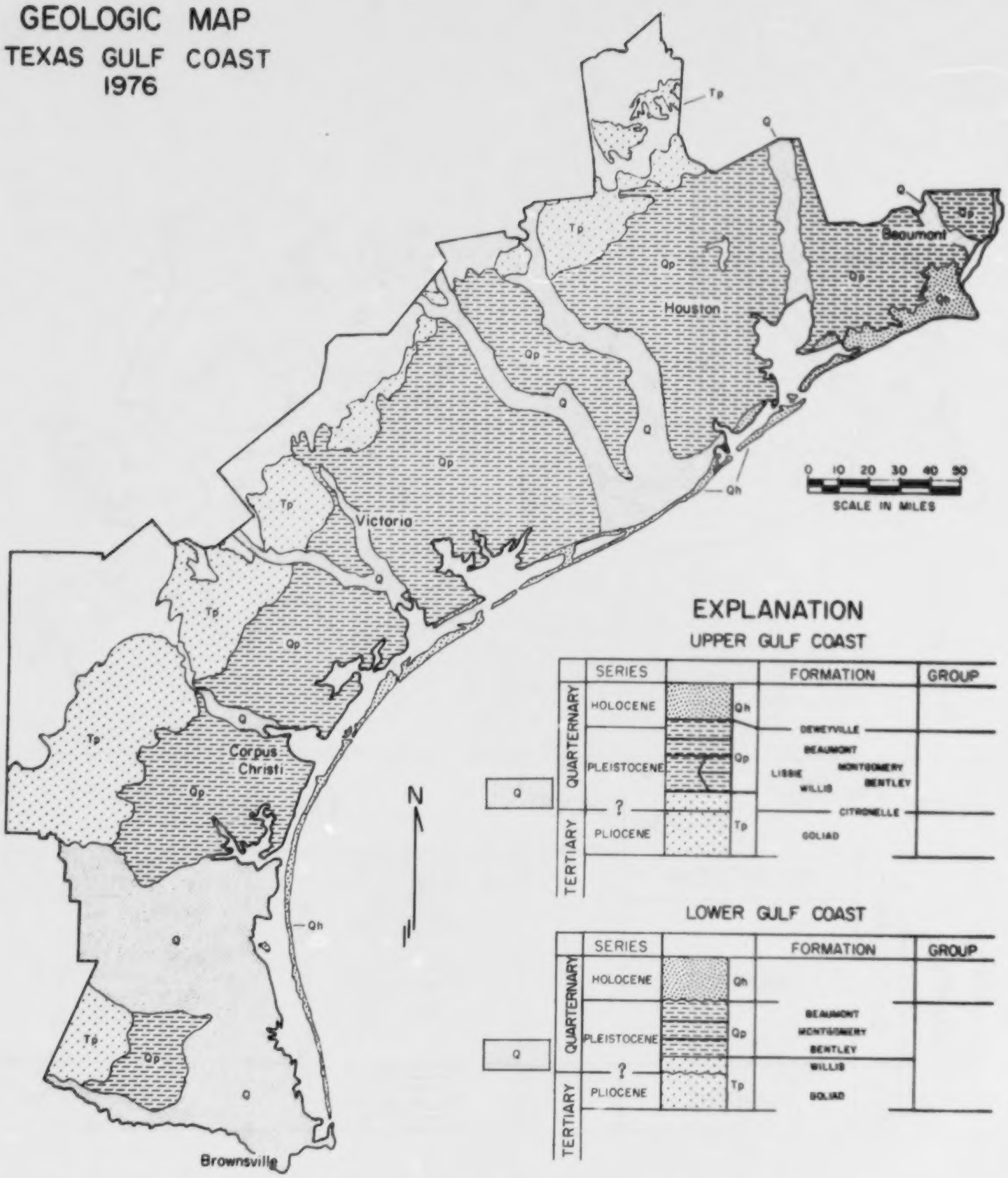
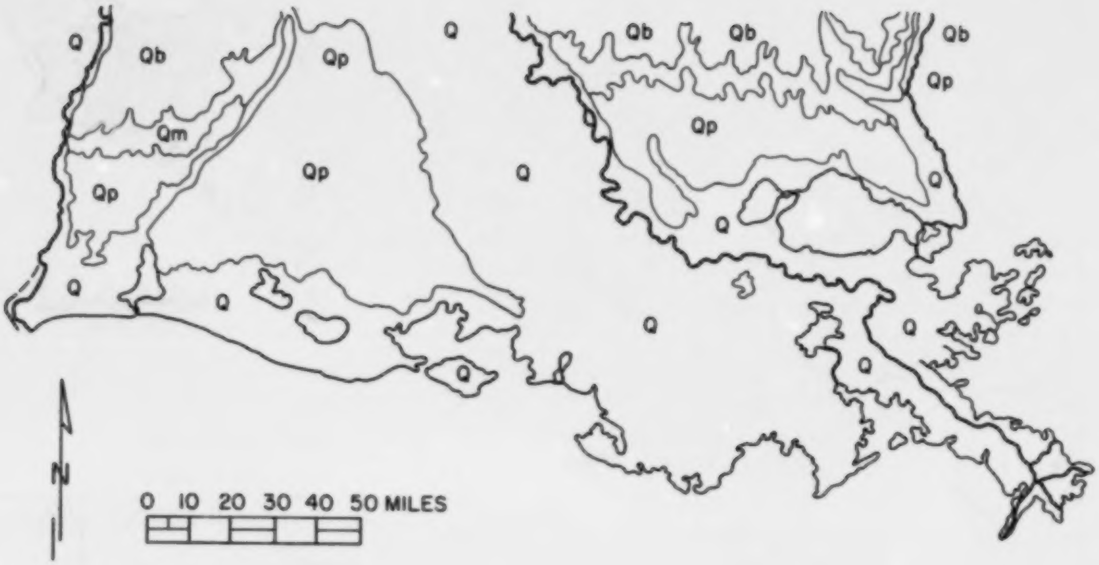

GEOLOGIC MAP
TEXAS GULF COAST
1976
Tp
Q
Qp
Beaumont
Qh
Houston
Victoria
Corpus Christi
Brownsville
0 10 20 30 40 50
SCALE IN MILES
N
EXPLANATION
UPPER GULF COAST
SERIES
FORMATION
GROUP
QUARTERNARY
HOLOCENE
PLEISTOCENE
TERTIARY
PLIOCENE
DEWEYVILLE
BEAUMONT
LISSIE
MONTGOMERY
BENTLEY
WILLIS
CITRONELLE
GOLIAD
?
LOWER GULF COAST
SERIES
FORMATION
GROUP
QUARTERNARY
HOLOCENE
PLEISTOCENE
TERTIARY
PLIOCENE
BEAUMONT
MONTGOMERY
BENTLEY
WILLIS
GOLIAD
?

Figure 4a. Texas System of Natural Laboratories, 1977, (prepared by University of Texas Bureau of Economic Geology from Brown and others, 1976, in press; Fisher and others, 1972, 1973; Groat and others, in preparation; McGowen and others; 1976 a,b).


Q
Qb
Qp
Q
Qb
Qb
Qb
Qm
Qp
Qp
Qp
Qp
Qp
Q
Q
Q
Q
Q
Q
Q
Q
Q
N
0 10 20 30 40 50 MILES

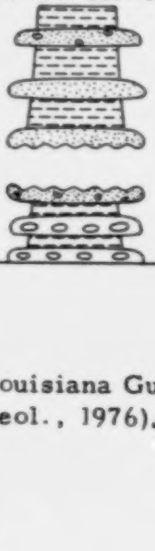
ERA	PERIOD	EPOCH	GROUP	LOUISIANA				
CENOZOIC	QUATERNARY	PLEISTOCENE		SCHEMATIC COLUMNAR SECTION 	TERRACE DEPOSITS	STREAM AND SHORE DEPOSITS		Q
		HOLOCENE				PRAIRIE	Qp	Qt
						MONTGOMERY	Qm	
						BENTLEY	Qb	
	TER.	PLIOCENE				WILLIANA		Tpw

Figure 4b. Surficial geologic map, Louisiana Gulf Coastal region (from Am. Assoc. Petroleum Geol., 1976).

delta plain sediments along the Texas Coast and an aeolian sand sheet in south Texas (Brown and others, 1976, in press; Fisher and others, 1972, 1973; Frazier, 1974; McGowen and others, 1976 a, b). Bay and estuarian sands and muds occur landward of the barrier islands and shore face sands and shelf muds dominate the coastal portion of the Gulf of Mexico. The Mississippi River has produced a large cone of deltaic sands and muds that extends into the Gulf of Mexico Basin. Throughout the Tertiary and Quaternary the same basic patterns of clastic sedimentation have occurred along the Gulf Coast such that sedimentary units at depth have modern analogues, either currently forming or exposed at the surface of the Gulf Coastal Plain.

The major structural features of the Gulf Coast are salt domes and systems of growth faults. Salt domes and associated salt ridges result from the upward movement of relatively low density diapirs of Jurassic Louann Salt through denser overlying clastic sediments. Growth faults may be related to several processes including differential compaction between adjacent masses of mixed sand and shale, and basinward slippage of coastal sediments along bedding planes (Bruce, 1973).

Growth fault systems along the Gulf Coast are a major factor in providing structural closure for hydrocarbon reservoirs. They may also serve as hydrologic barriers to the up dip migration of formation fluids, providing a seal for some potential geopressured-geothermal reservoirs. Conversely, they may provide migration routes for formation fluids.

Recent fault activity has been clearly demonstrated along the Gulf Coast of Texas (Kreitler, 1976) and most of the active surface faults appear to be extensions of growth faults recognized in the subsurface. However, gradual slippage along these fault planes has resulted in few, if any, detectable earthquake shocks. The coastal areas of Texas and Louisiana are considered as low seismic risk areas.

The surface morphology of the Coastal Plain of Texas is dominately a flat featureless plain, composed of relic Pleistocene deltaic plains broken here and there by wide river valleys and estuaries and rarely by low mounds. The mounds are the land surface expression of salt domes. South of Baffin Bay about 30 miles south southwest of Corpus Christi an extensive sand sheet occurs with numerous active and inactive eolian features--dunes, sand sheets, and deflation basins. The coastal plain is separated from the Gulf of Mexico by an extensive system of barrier islands, bays, and lagoons, extending from Galveston Bay to the Rio Grande. The coast of Louisiana is dominated by the Mississippi River delta and remnants of older abandoned Mississippi River deltas. Westward from the Mississippi delta complex, Louisiana and eastern Texas are largely coastal marsh and swamp interspersed with a system of low subparallel chenier ridges each of which marks the position of an older abandoned shoreline.

Soils

A wide variety of soils are present along the coastal plain but several generalizations can be made (figure 5a, b). Much of the area is poorly to moderately well drained. Clayey soils are only slightly permeable and are expansive and corrosive and have a low bearing capacity. Loamy and sandy soils are underlain by poorly permeable, clayey B horizons with notable exceptions being modern and ancient beach and barrier island sands. Marsh lands are underlain by organic rich soils, peats and mucks. Both shrink-swell and corrosion potentials are high for these soils. Bearing capacity is very low.

Vegetation

Marked diversity in climate and vegetation occur along the Texas-Louisiana coastal area (figure 6a, b). Rainfall decreases from over 152 centimeters (60 inches) per year in southern Louisiana to less than 66 centimeters (26 inches) per year in southern Texas. Mean annual temperature increases from 21°C (70°F) in southern Louisiana to 23°C (74°F) in southern Texas. Corresponding largely to the change in available moisture the major vegetation associations change from extensive coastal swamp and marsh in Louisiana to coastal marsh in eastern Texas to prairie grasses with hardwood mottes in central Texas to chaparral in southern Texas. Salt marsh is locally present all along the Texas coast.

It is important to recognize that a hierarchy of systems--geologic, soil, vegetation, and zoologic--are present on the Gulf Coast. The interaction of the geology and the physical processes--primarily tides and climate--control the areal distribution of other aspects of the coastal land area (McGowen et al, 1976 a, b; Fisher et al, 1973, 1972; Brown et al, 1976, in press). Soils are largely dependant on the character of the geologic substrate, topography, and climate; natural vegetation is dependent on soil type and climate; and the animal life that occupies the region is in many cases dependent on vegetation. Tidal range controls the landward extent of salt marsh vegetation, while for many other species the range in available moisture controls to a large extent their geographic range.

Land Use

Current Land Use on the Texas Gulf Coast is largely as cropland and range land (McGowen et al, 1976 a, b; Fisher et al, 1973, 1972; Brown et al, 1976, in press) (figure 7A). Near the Louisiana-Texas border forested lands and wetlands increase in importance. The Gulf Coast of Louisiana is

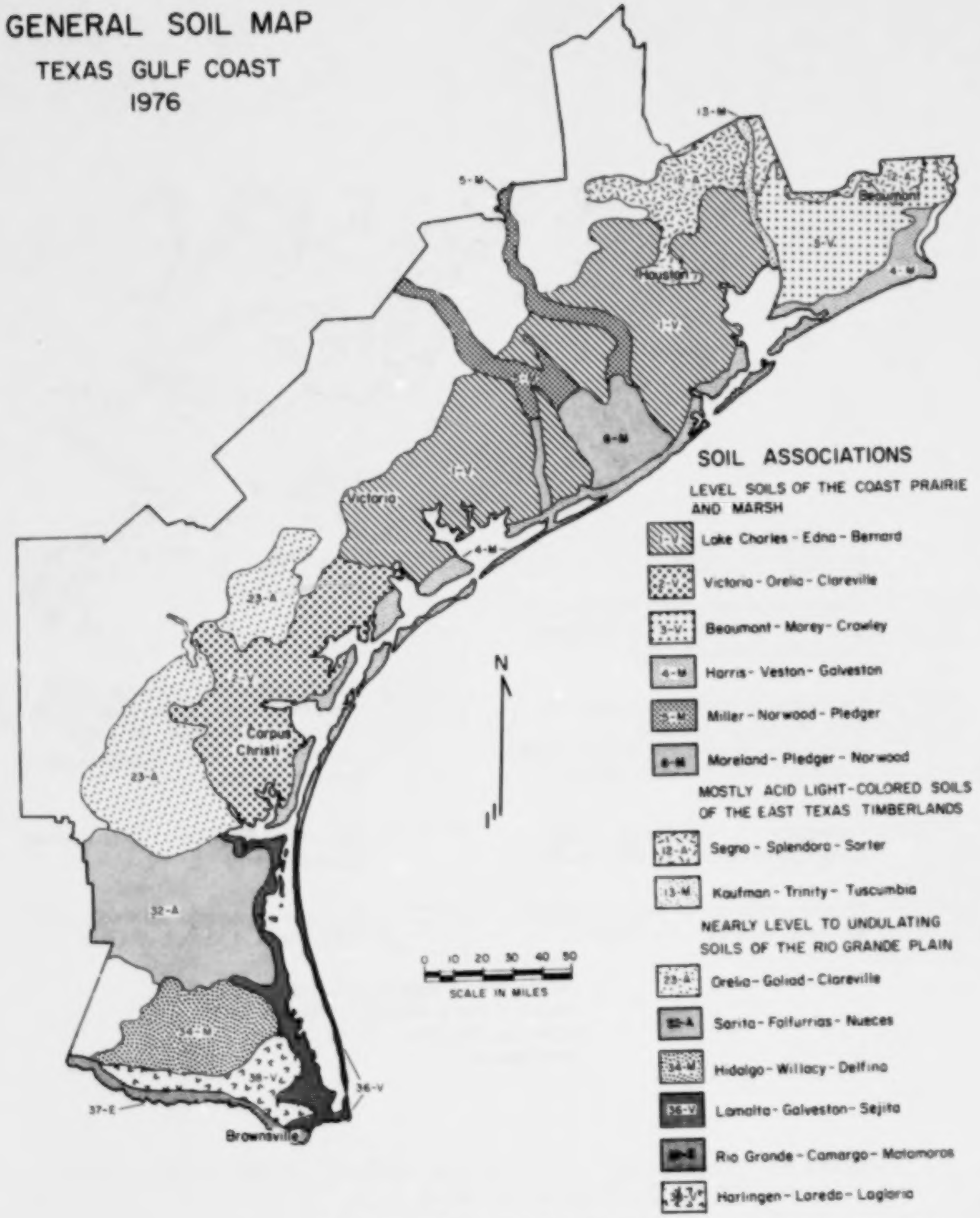
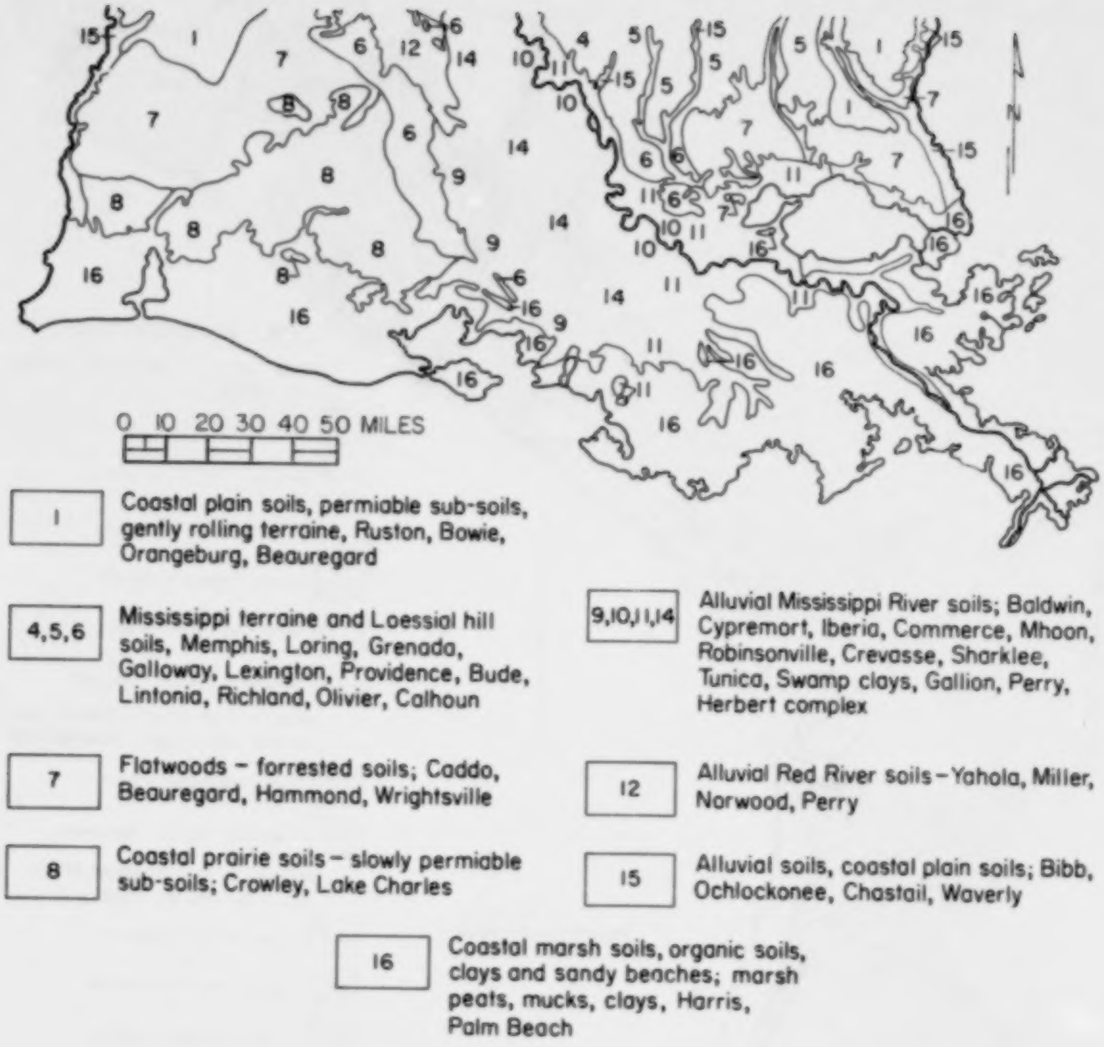

GENERAL SOIL MAP
TEXAS GULF COAST
1976
13-M
5-M
12-A
Beaumont
3-V
4-M
Houston
1-V
6-M
Victoria
4-M
23-A
2-V
Corpus Christi
23-A
32-A
34-M
38-V
36-V
37-E
Brownsville
N
0 10 20 30 40 50
SCALE IN MILES
SOIL ASSOCIATIONS
LEVEL SOILS OF THE COAST PRAIRIE AND MARSH
1-V Lake Charles - Edna - Bernard
2-V Victoria - Orelia - Clareville
3-V Beaumont - Morey - Crowley
4-M Harris - Veston - Galveston
5-M Miller - Norwood - Pledger
6-M Moreland - Pledger - Norwood
MOSTLY ACID LIGHT-COLORED SOILS OF THE EAST TEXAS TIMBERLANDS
12-A Segno - Splendora - Sorter
13-M Kaufman - Trinity - Tuscumbia
NEARLY LEVEL TO UNDULATING SOILS OF THE RIO GRANDE PLAIN
23-A Orelia - Goliad - Clareville
32-A Sarita - Falfurrias - Nueces
34-M Hidalgo - Willacy - Delfino
36-V Lomalto - Galveston - Sejita
37-E Rio Grande - Camargo - Matamoros
38-V Harlingen - Laredo - Lagloria

Figure 5a. Texas System of Natural Laboratories, 1977 (compiled by the University of Texas Bureau of Economic Geology).



1	Coastal plain soils, permiable sub-soils, gently rolling terraine, Ruston, Bowie, Orangeburg, Beauregard
4,5,6	Mississippi terraine and Loessial hill soils, Memphis, Loring, Grenada, Galloway, Lexington, Providence, Bude, Lintonia, Richland, Olivier, Calhoun
7	Flatwoods – forrested soils; Caddo, Beauregard, Hammond, Wrightsville
8	Coastal prairie soils – slowly permiable sub-soils; Crowley, Lake Charles
9,10,11,14	Alluvial Mississippi River soils; Baldwin, Cypremort, Iberia, Commerce, Mhoon, Robinsonville, Crevasse, Sharklee, Tunica, Swamp clays, Gallion, Perry, Herbert complex
12	Alluvial Red River soils – Yahola, Miller, Norwood, Perry
15	Alluvial soils, coastal plain soils; Bibb, Ochlockonee, Chastail, Waverly
16	Coastal marsh soils, organic soils, clays and sandy beaches; marsh peats, mucks, clays, Harris, Palm Beach

Figure 5b. General Soil map, Louisiana Gulf Coastal region, (from U. S. Geol. Survey, 1970)

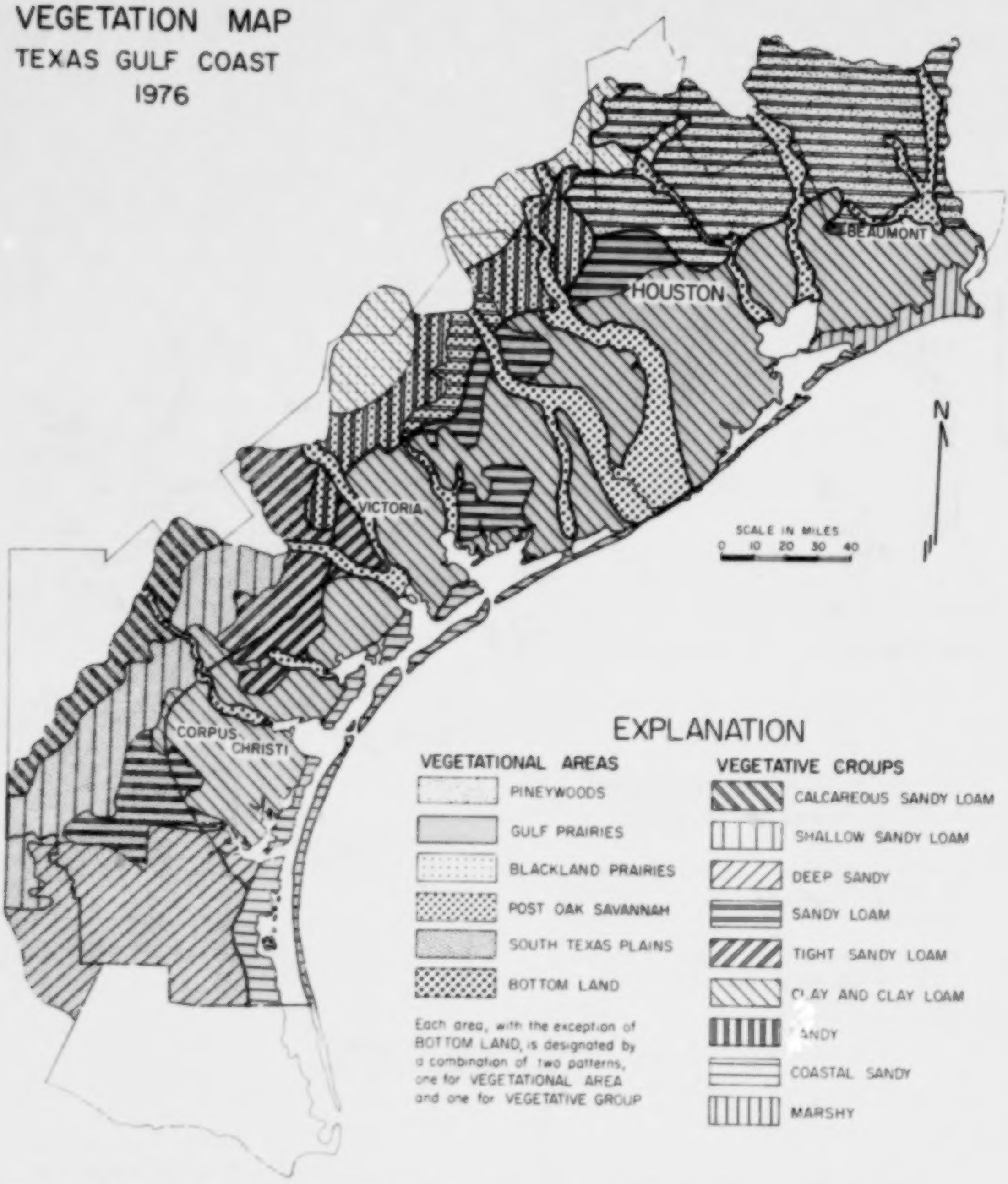

VEGETATION MAP
TEXAS GULF COAST
1976
BEAUMONT
HOUSTON
VICTORIA
CORPUS CHRISTI
N
SCALE IN MILES
0 10 20 30 40
EXPLANATION
VEGETATIONAL AREAS
PINEYWOODS
GULF PRAIRIES
BLACKLAND PRAIRIES
POST OAK SAVANNAH
SOUTH TEXAS PLAINS
BOTTOM LAND
Each area, with the exception of BOTTOM LAND, is designated by a combination of two patterns, one for VEGETATIONAL AREA and one for VEGETATIVE GROUP
VEGETATIVE GROUPS
CALCAREOUS SANDY LOAM
SHALLOW SANDY LOAM
DEEP SANDY
SANDY LOAM
TIGHT SANDY LOAM
CLAY AND CLAY LOAM
SANDY
COASTAL SANDY
MARSHY

Figure 6a. Texas System of Natural Laboratories, 1977, (prepared by University of Texas Bureau of Economic Geology from Brown and others, 1976, in press; Fisher and others, 1972, 1973; Groat and others, in preparation; McGowen and others; 1976 a,b).

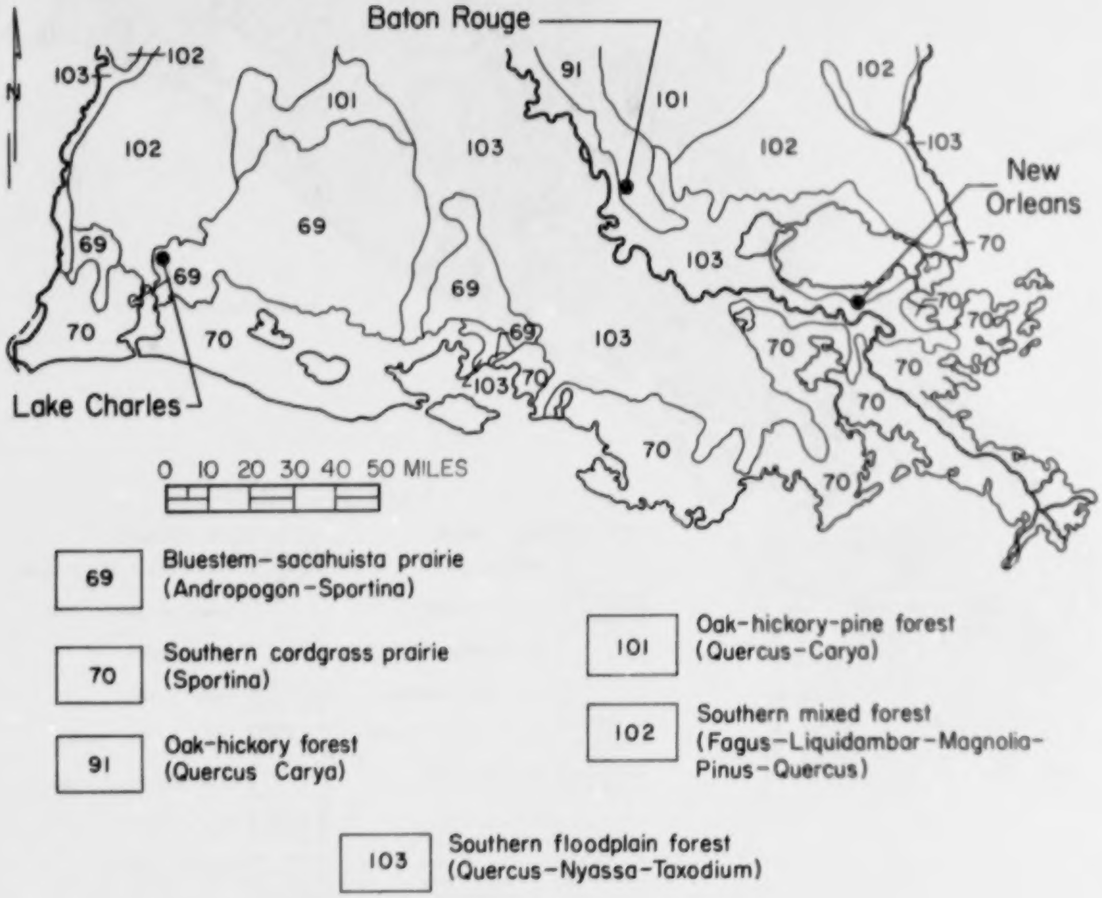

N
Baton Rouge
New Orleans
Lake Charles
103
102
101
103
69
69
69
70
70
69
69
103
70
103
91
101
102
102
103
70
103
70
70
70
70
70
70
70
70
0 10 20 30 40 50 MILES
69 Bluestem–sacahuista prairie (Andropogon–Spartina)
70 Southern cordgrass prairie (Spartina)
91 Oak-hickory forest (Quercus Carya)
101 Oak-hickory-pine forest (Quercus–Carya)
102 Southern mixed forest (Fagus–Liquidambar–Magnolia–Pinus–Quercus)
103 Southern floodplain forest (Quercus–Nyassa–Taxodium)

Figure 6b. General vegetation map, Louisiana Gulf Coastal region (from U. S. Geol. Survey, 1970)

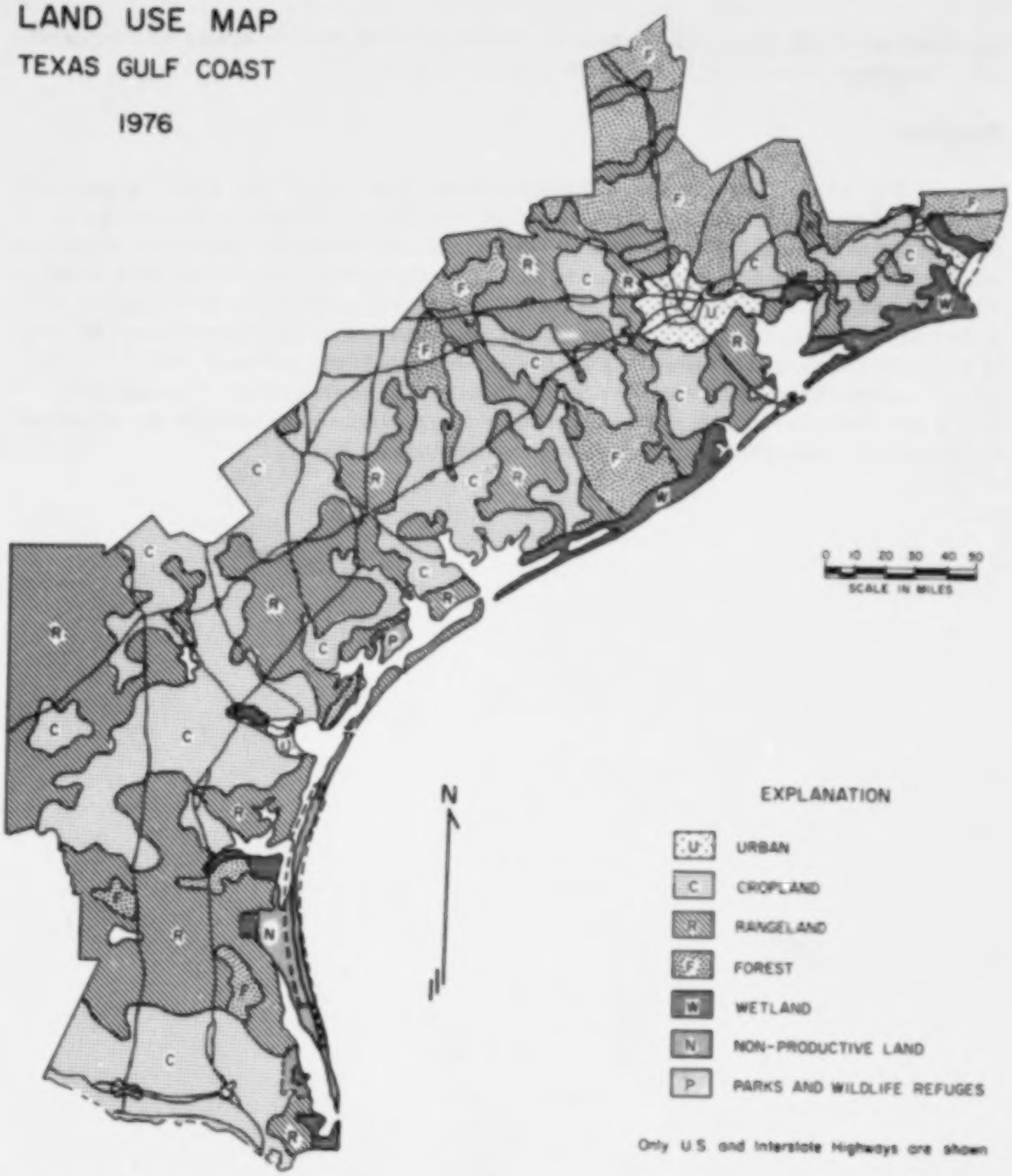

LAND USE MAP
TEXAS GULF COAST
1976
0 10 20 30 40 50
SCALE IN MILES
N
EXPLANATION
U URBAN
C CROPLAND
R RANGELAND
F FOREST
W WETLAND
N NON-PRODUCTIVE LAND
P PARKS AND WILDLIFE REFUGES
Only U.S. and Interstate Highways are shown

Figure 7a. Texas System of Natural Laboratories, 1977, (prepared by University of Texas Bureau of Economic Geology from Brown and others, 1976, in press; Fisher and others, 1972, 1973; Groat and others, in preparation; McGowen and others; 1976 a,b).

predominately in forested lands and wetlands with major areas of cropland and rangeland along the higher elevations (figure 7b).

Benefits

The major benefit to be derived from phase I of this study is the compilation of current data and data sources that have bearing on the problem of potential environmental impacts to Gulf Coast ecosystems resulting from the development of geothermal resources. The complete study including both Phase I and Phase II will provide baseline information upon which more detailed environmental assessments of geothermal resource areas may be built if and when they are needed. Furthermore, the study presents an overview of the currently understood limited potential for geothermal development along the Gulf Coast and the environmental resources that might be impacted by geopressured-geothermal resource development.

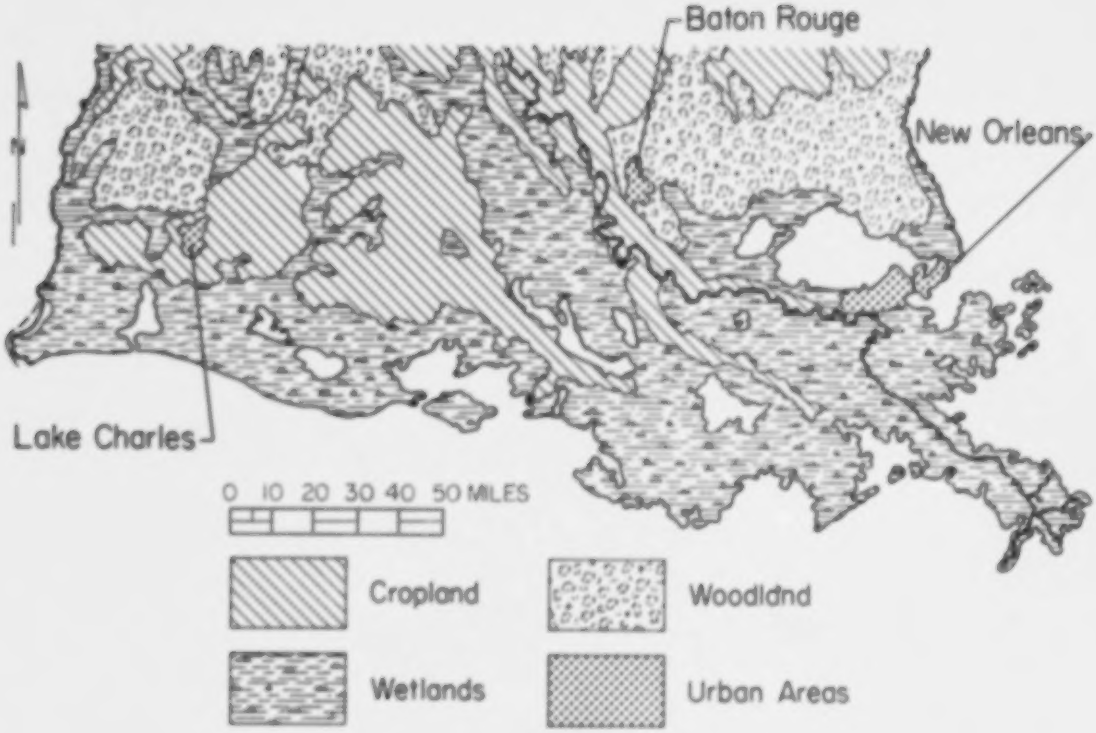

Baton Rouge
New Orleans
Lake Charles
N
0 10 20 30 40 50 MILES
Cropland
Woodldnd
Wetlands
Urban Areas

Figure 7b. General land use map, Louisiana coastal region (from U. S. Geol. Survey, 1970)

OCCURRENCE OF GEOPRESSURED FLUIDS IN THE GULF COAST

Pressures in the earth's crust may be considered in several forms--geostatic pressure, hydropressure and geopressure (figure 8)--each of which can be expressed as the product of weight density (D), times height (h), or mass density (d) times height (h) times the acceleration due to gravity (g):

$$P = Dh$$

$$P = dhg$$

Geostatic pressure results from the combined weight of overburden including rock material, unlithified sediment, pore fluids, and overlying water if any. The terms hydropressure and geopressure apply to the fluids contained within rock pore spaces. Hydropressure is the sum of hydrostatic pressure (P_h)--the product of the fluid column height (h) times its density (d) times the gravitational constant (g) and hydrostatic back pressure (hgp). Hydrostatic back pressure is minute and results from the continuous upward migration and eventual escape of fluids from the rock column (Stuart, 1970).

$$P_h + (hdg) + (hgp)$$

If the densities of the pore fluids in a column of rock are known and if the rate of upward migration of the fluids are known in addition to the height of the column of rock then a formation pressure gradient (FPG) can be calculated. In hydropressured systems, where there is communication between pores, hydropressure increases at a relatively uniform rate with depth. In the Gulf Coast the formation pressure gradient is 977 N/m^2 per meter (0.465 psi per foot).

Geopressure (Gp) may then be defined as pore pressures that exceed the projected hydropressure for any depth.

To understand the genesis of geopressured pore fluids it must be recognized that most sedimentary rocks are deposited underwater and that pore spaces between grains are filled with sea water or fresh water. Even

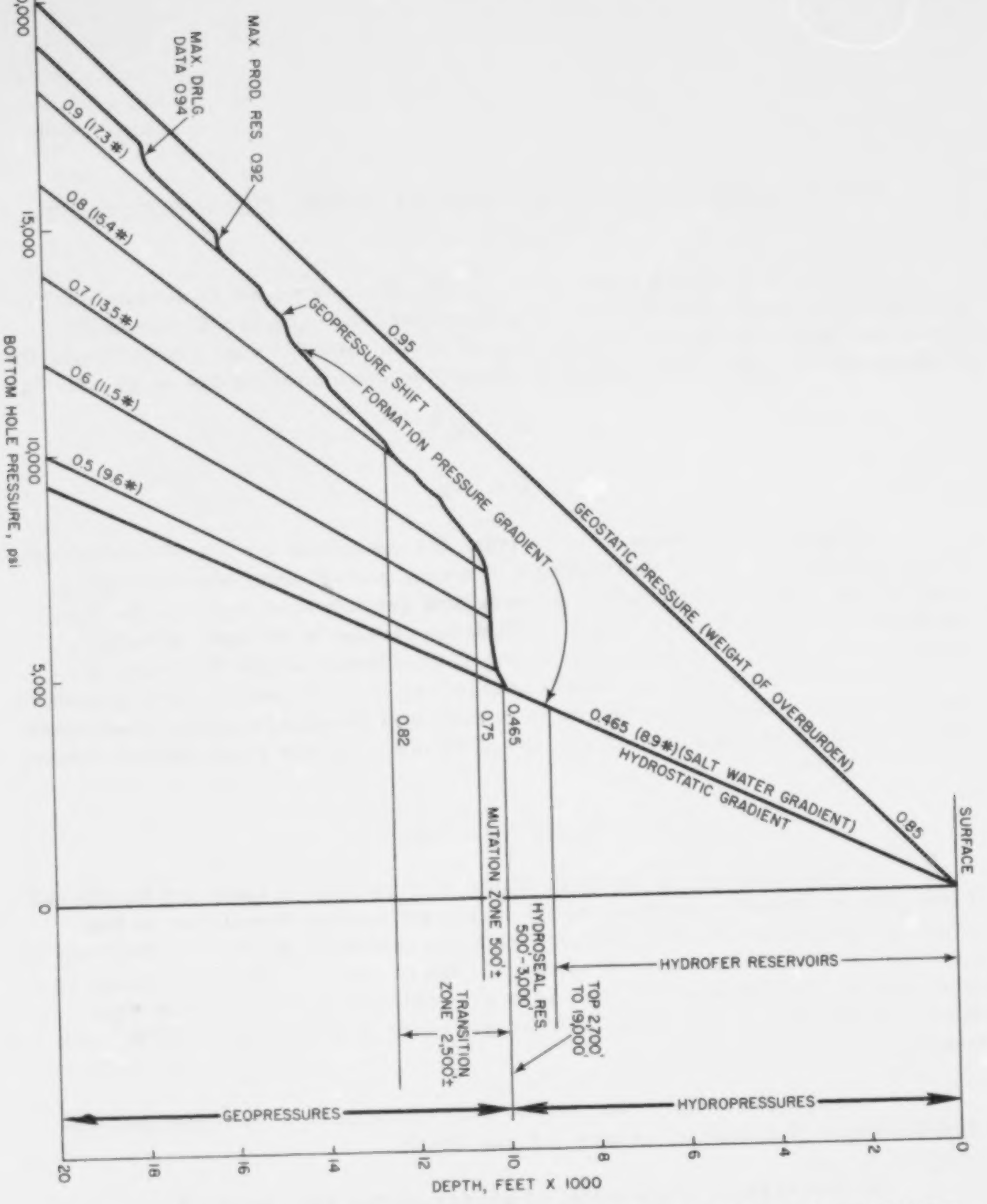


Figure 8. Diagram illustrating normal and geopressure terminology for the Gulf Coastal region (Stuart, 1970)

those sediments deposited above water soon become water saturated after burial. As sediments are buried deeper and deeper by additional deposits the weight of the overburden causes compaction and squeezes out water from between grains of sediment. This process is particularly important in muddy or clayey sediments where water may occupy 60 to 80 percent of the volume of the original sediment mass. Compaction and dewatering of sediments is an ongoing process as long as pore waters are not sealed off.

If pore waters in a volume of sediment become sealed off from overlying formation waters--in effect sealed in an envelope of impermeable sediments--then pore waters will probably become geopressured. Geopressures (Pg) are the sum of normal hydropressure (P_h) plus some additional pressure components ($f_t + f_{gsp}$) (Stuart, 1970). The major sources of additional pressure are twofold: first, with continuing sedimentation an increased load of overburden is applied and the sealed off pore waters of a volume of rock at depth begin to support not only the weight of the overlying column of water but a component of the weight of the overlying column of rock (f_{gsp}). Second, because pore water circulation is restricted and because of increasing depth of burial, temperature of geopressured fluids increase (f_t). With the increased temperatures of the pore fluids, fluid pressures increase such that

$$Pg = P_h + f_{gsp} + f_t$$

STORAGE OF HEAT ENERGY IN GEOPRESSURED FLUIDS

Dissipation of heat at the earth's surface occurs at a mean rate of 1.5 microcalories per square centimeter per second. Heat dissipation has resulted in a geothermal gradient in the earth's surficial rocks such that mean rock temperature increases approximately 30°C (54°F) per kilometer of depth. Normal temperature gradients for the Texas Gulf Coast range from 29 to 40°C per kilometer. Where the insulating properties of the rock at depth are high, the geothermal gradient increases markedly. The sediments of the geopressured zone are apparently undercompacted with respect to overlying sediments, and as a consequence contain a higher proportion of water filled porespace (Lewis and Rose, 1970). The coefficient of thermal conductivity of water is ~ 1 mcal/s cm °C while the heat conductivity of sandstone ranges up to 16 mcal/s cm °C and shale ranges up to 4 mcal/s cm °C. Hence sediments containing more water tend to transmit heat less efficiently than sediments containing less water. For this reason rock and fluids in the geopressured zone of the Gulf coast have higher geothermal gradients than normally pressured sediments. Temperatures in the geopressured zone of Texas have locally exceeded 283°C (520°F).

RECOGNITION OF GEOPRESSURED-GEOTHERMAL RESOURCES IN THE LOUISIANA-TEXAS GULF COAST

Texas

The potential energy resources contained within the geopressured sediments of the Texas and Louisiana Gulf Coast were first recognized by Hottman (1966, 1967). Later Jones (1969, 1970), Wallace (1970), Dorfman and Kehle (1974), and Papadopulos and others (1975) among many others described the potential geothermal resources of the area. Early assessments of geopressured-geothermal resources were universally optimistic. Papadopulos and others (1975) estimated that recoverable thermal and mechanical energy from geopressured-geothermal fluids of the Gulf Coast would range from 2880, to 19, 580 megawatt centuries (14, 400 to 108, 650 mw (20 years)). Dorfman and Kehle (1974) suggested that Tertiary sediments along the Gulf Coast would contain a reserve of at least 20,000 megawatt centuries of electrical power. Furthermore, this was in addition to any methane or other hydrocarbons dissolved in the geothermal fluids.

In defense of these early estimates it should be understood that detailed regional mapping of sand distribution, sand thickness, temperatures, and rock permeabilities within the geopressured zone were not generally available. Recent work by Bebout and others (1975, 1976, 1977) has shown that geothermal reservoirs of sufficient size, temperature and permeability --91 meters (300 feet) thick, 129 square kilometers (50 square miles) in area, 150°C (300°F) temperature, 20 millidarcies--to support one 25 megawatt (20 year) generating facility are not common. Rock permeabilities rarely exceed 1 or 2 millidarcies in the geopressured zone of south Texas. To date only one area on the Texas Coast has been identified with adequate size, temperatures and porosity to be considered as a strong candidate for testing by drilling a well. Four other areas have been identifed as possible sites.

Based largely on geologic evidence it appears that geothermal resources within the Frio Formation may be limited. Swanson and others (1976) concluded that the Vicksburg Formation which immediately underlies the Frio Formation does not have sufficient permeability in south Texas to yield flow rates of 100,000 bbls/day for sustained periods of time.

Recent geothermal resource evaluation in the Vicksburg Formation along the northern Texas Coast and in the Wilcox Formation indicates that geopressured-geothermal resource fairways are probably more numerous than in the Frio Formation (Don Bebout, 1977, personal communication).

Louisiana

In Louisiana analyses of 4991 wells were made to provide data on total sand thickness and on drilling mud weight ranges, which are relative measures of geopressure (Hawkins, 1976). Computer maps of the distribution of total sand thickness and mud weight were prepared for southern Louisiana for depth intervals of 3048 to 3657 meters, 3657 to 4266 meters, 4266 to 4875 meters and 4875 to 5484 meters (10,000 to 12,000 feet, 12,000 to 14,000 feet, 14,000 to 16,000 feet and 16,000 to 18,000 feet). Visual comparison of areas of high pressure (high mud weight) and high total sand thickness have led to the identification of approximately 50 areas of interest (Hawkins, 1977, personal communication) of which three of the most promising are shown on figure 3. The stratigraphic units contained in these areas are not known.

THE GEOTHERMAL RESOURCES

CURRENTLY RECOGNIZED GEOPRESSURED-GEOTHERMAL PROSPECT AREAS AND FAIRWAYS

Texas

Bebout and others (1975, 1976a, b) have identified seven potential geothermal fairways along the coast of Texas (figure 2). The term fairway is here used in the sense of an area of interest. Fairways are underlain by sands of sufficient thickness and temperature to contain potentially enough geothermal fluids to supply a 25 mw generating facility. The ideal prospect model is a reservoir with a volume of an least three cubic miles--cumulative sand thickness of greater than 91 meters with an areal extent of 129 square kilometers, greater than 150°C corrected subsurface fluid temperature, permeability greater than 20 millidarcies, and water saturated with methane (Bebout and Loucks, 1976). Within the fairways 3 prospect areas have been defined--the Armstrong, Nueces and Brazoria prospects. According to Bebout and Loucks (1976) the sand bodies for the three prospect areas range in cumulative thickness from 61 to 183 meters (200 to 600 feet) and each extends over an area of 125 square kilometers (50 square miles), with the exception of the Brazoria prospect area. Fluid temperatures in the three prospective reservoirs range from 121°C (250°F) to at least 165°C (330°F). Permeability data are sparse, but suggest that permeabilities of 18-20 millidarcies are to be found at depths of (11,000-12,000 feet). At this depth fluid temperatures are about 121°C (250°F) and while temperature increases with depth, permeability decreases in hotter deeper reservoirs. The large reservoirs of hundreds of square miles extent with large permeabilities predicted by previous workers do not exist in the Frio Formation; rather, only seven fairways and three prospect areas have been recognized (Table I). Of the prospect areas, the Brazoria County area is the only area that has been recommended for test drilling.

Table I—Fairway characteristics

Fairway Location	Extent of Sand Bodies	Temperature Range	Limiting Factors Permeability/Reservoir Continuity
Hidalgo, Willacy, and Cameron Counties	Deltaic sands 100-600 ft thick below 9,000 ft	—	Very low permeability
Nueces County	Deltaic sands high sand/shale percentage below 9,000 ft	—	Very low permeability, low temperature
Armstrong Ranch, Kenedy County	—	—	—
Aransas, Nueces, and San Patricio Counties	500 ft thick 200 sq miles 10,000-16,000 ft deep	300-320° F	Very low permeability; numerous faults result in questionable reservoir continuity
South-central Matagorda County	200 ft thick 100 sq miles 15,700 ft deep	300° F	Very low permeability
Northeast Matagorda County	150 ft thick 13,700 ft deep	300° F	Very low permeability
Brazoria County	1,200 ft of sand below 12,600 ft	278-314° F	Low to moderate permeability 18-20 millidarcys locally

From Bebout and others (1975a, b).

Louisiana

Three prospect areas have been delineated in southern Louisiana and detailed geologic studies have been completed for two of these (figure 3) (Hawkins, 1976). The South Midland Project in Acadia Parish exhibits a net sand thickness of 91 meters (300 feet), average porosity is 30.7 percent and average permeability is 413 millidarcies and uncorrected temperature range from 100°C to 140°C (212°F to 284°F).

The West Lockport Prospect is in Calcasieu Parish. Average net sand thickness is 100 feet and temperature range from 100°C to 145°C (212° F to 295°F). No porosity or permeability data are available here.

PHYSICAL AND CHEMICAL PROPERTIES OF GEOTHERMAL FLUIDS

Most sedimentary rocks are derived from sediment originally deposited in the marine environment. At the time of deposition sea water was present in pore spaces between the individual sediment grains. In the process of burial and compaction pore space in sediments decreases. The remaining pore spaces are filled with fluids; usually a brine, but locally hydrocarbons displace the brines. In a general fashion formation waters of Gulf Coast sediments increase in salinity with depth. Schmidt (1973) has shown that concentrations of dissolved solids in produced waters from sandstones and in interstitial waters from both shales and sands increase with depth. Total dissolved solid (TDS) concentrations from 100,000 to 200,000 parts per million (ppm) were observed for depths ranging from 914 to 3962 meters (3,000 to 13,000 feet) in the Manchester field and Hackberry fields in Louisiana. In Texas, Fowler (1968) also observed an increase in formation water salinity from 40,000 to 90,000 parts per million from 2438 to 3658 meters (8,000 to 12,000 feet) in the West and East Chocolate Bayou fields. Schmidt (1973) and Jones (1975) have both shown that substantial decreases in TDS concentrations can occur in geopressured fluids in comparison to TDS concentrations in normally pressured fluids sediments immediately overlying the geopressured zone. Nevertheless analyses of fluids from the geopressured zones of both Texas and Louisiana indicate the TDS ranges from less than 20,000 ppm to as much as 345,000 ppm may be expected. Figure 9 illustrates analyses of geopressured fluids from 37 wells along the Gulf Coast. The values of the concentrations shown here are minimum values. For many of the analyses the sampling technique and the well conditions under which the sample was collected is not known. Water samples from wells with high gas-water ratios and low volume of produced water are apt to yield water samples with low salinities. In these wells formation waters may be diluted with water vapor condensed from natural gas (Kharaka and others, 1976). For this reason the analyses shown in figure 9 are for samples whose TDS were in excess of sea water (35,000 ppm TDS). Analyses of water samples from wells with high gas/water ratios producing from geopressured horizons were not used because of the potential for substantial dilution by waters of condensation.

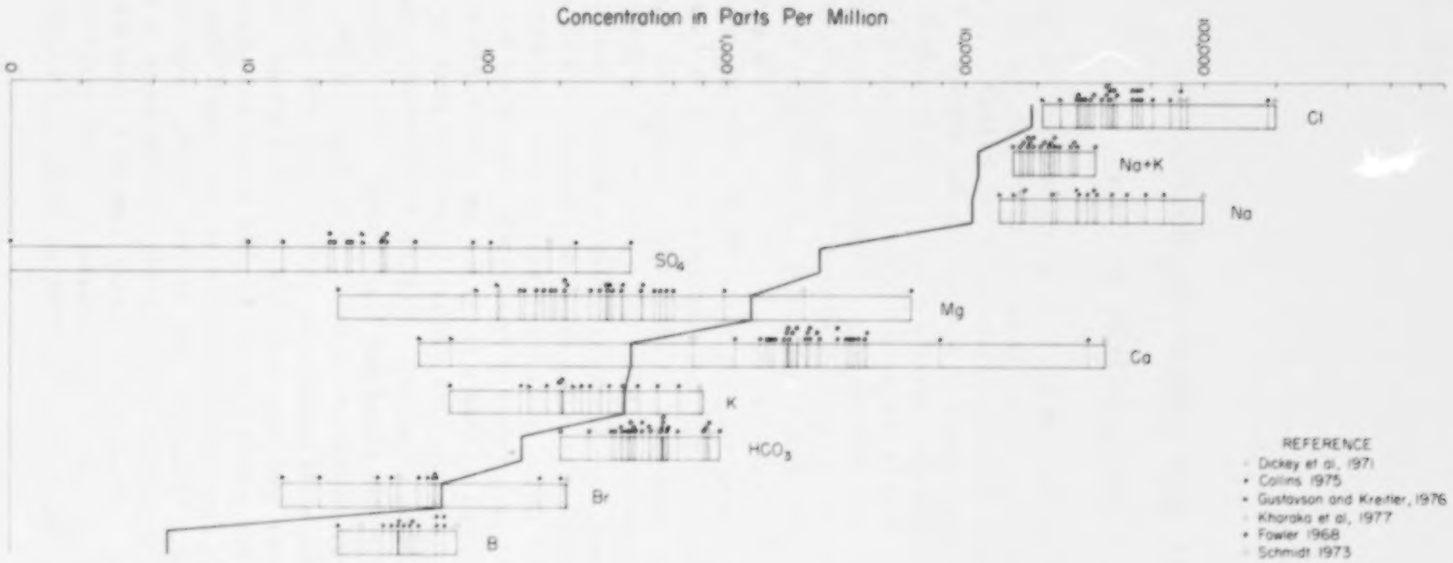


Figure 9. Distribution of dissolved ions from 37 geopressured fluid samples from Louisiana and Texas. Vertical segments of the heavy continuous line mark concentrations of ions in normal sea water.

COMPARISON OF GEOTHERMAL FLUIDS TO THE WATERS OF THE GULF OF MEXICO AND COASTAL BAYS AND LAGOONS

Figure 9 illustrates the concentrations of major dissolved ions in geopressured water in comparison to the concentrations of ions in normal sea water (Gulf of Mexico). Data on trace elements in geopressured fluids is limited and was not available for all but two of the analyses in Figure 9. For geopressured fluids Na^+, Cl^-, Ca^{++}, HCO^{3-}, B^{+++} ions have been recorded in concentrations of up to 1 order of magnitude greater than sea water with Ca^{++} ion concentrations sometimes in excess of an order of magnitude higher. Mg^{++} ions are in concentrations of as much as an order of magnitude less than sea water. K^+ and Br^- ion concentrations bracket their concentrations in sea water and occur in concentrations as much as one half order of magnitude more or less than their normal sea water concentrations.

The normal concentration of SO_4^{--} ions in sea water is nearly 2450 ppm. In geopressured fluids concentrations may be two orders of magnitude less; several analyses indicate that SO_4^{--} ions are missing altogether.

It is important to recognize that geopressured fluids are not simply concentrated sea water with a regular and systematic increase in all dissolved ions. Geopressured fluids are rather complex solutions that are in part the result of fluid and ion migrations and chemical reactions that accompany the burial of sediment and its subsequent diagenesis. Therefore, in the event that geopressured fluids are released into bays, lagoons, or the Gulf of Mexico the fluid release cannot be simply equated to an input of concentrated sea water, for the balance of ions in geopressured fluids differs markedly from the ionic balance of normal sea water.

The bays, lagoons, lakes, and marshes that lie landward of the barrier islands and beaches of Texas and Louisiana vary significantly in salinity, both geographically and with time (Table II). The salinities of coastal water bodies vary mainly with respect to precipitation. Other factors such as strong northerly or southerly winds can, however, affect water levels within coastal water bodies and thereby significantly alter the circulation of water into or out of coastal water bodies. In a general fashion the salinities of coastal water bodies increase westward and southward in response to decreasing annual rates of precipitation and increasing rates of evaporation. With few exceptions the salinities of Louisiana coastal marshes and lakes are less than 15,000 ppm. Maximum salinities of 10 to 20,000 ppm are known for Sabine Lake on the Texas-Louisiana border and maximum salinities for portions of Alazan Bay in south Texas may reach 74,000 ppm. Following heavy rainfalls--hurricanes or tropical storms--coastal water bodies may sustain salinities of less than 10,000 ppm for more than 50 percent of their water volume. The wide variation in salinities experienced by any single water

Table II—Salinity and temperature ranges for coastal water bodies adjacent to geopressured-geothermal fairways

Area *and associated fairway*	**Salinity Range** *Parts per thousand*			**Temperature Range** **Celsius**	
	Maximum	**Average**	**Minimum**	**Maximum**	**Minimum**
West Bay *Brazoria County*	34 - 36	24 - 30	10	—	—
East Matagorda Bay *Matagorda County*	20 - 24	10 - 14	8 - 10	September 29.5 - 27.6	May 25.8 - 26.8
Corpus Christi Bay *Nueces County*	43 - 45	32 - 38	3 - 11	—	—
Redfish Bay	44	37	9 - 10	February 11.1 - 12	July 32 - 27.7

From Ratclaff, 1976.

body over a time period is due to natural processes and has been shown to be beneficial to the overall health and productivity of the biologic communities of the bays. Although under some circumstances the introduction of geothermal fluids into hypersaline waters such as Alazan Bay could reduce the salinity of the Bay, the salinities of most coastal water bodies would be increased locally if geothermal fluids were introduced into them. Furthermore, the ionic balance of geothermal fluids may differ substantially from the ionic balance of coastal water bodies which are largely mixtures of fresh and sea water.

METHANE IN GEOTHERMAL FLUIDS

Papadopulos and others (1975) have estimated the geopressured-geothermal fluids along the United States Gulf Coast to be saturated in methane. Methane usually represents more than 95 percent of the dissolved gases in normally pressured Gulf coast formation water, the remaining 5 percent consisting of heavier hydrocarbons, nitrogen and carbon dioxide. Estimated methane contents range from 6.7 to 18.2 standard m^3 of methane per m^3 of formation fluid for the coastal portion of Louisiana (Papadopulos and others, 1975). Methane contents range from 7.8 to 9.9 standard m^3 per m^3 for the coastal portion of Texas [Papadopulos and others (1975) provide a map of methane concentration along the Gulf Coast and data pertaining to methane concentration, expected formation water salinity and expected temperature ranges].

COMMERCIAL DEVELOPMENT OF GEOTHERMAL RESOURCES

Geopressured-geothermal fluids of the U. S. Gulf Coast may be producible from reservoirs underlying a variety of coastal environments--the Gulf of Mexico, estuaries, bays, lagoons, marsh land, barrier islands and coastal lowlands. Although production wells could be drilled in any of these environments the generating and disposal facilities are likely to be on land.

The commercial development of geothermal resources can be described in terms of three location scenarios:

1. The first scenario places production, generating and disposal facilities on coastal lowlands or uplands where access will be available by roads. For the purposes of this report it is assumed that the generating facility will occupy a relatively small area within a network of production wells. Furthermore, it is assumed that spent fluids will be disposed of via reinjection wells and that the network of reinjection wells would occupy the same area as the production wells (figure 10). In this scenario a minimum of land area would be impacted directly as well sites, pipelines and access roads to the well sites, storage ponds and generating plant site.

2. The second scenario places generating production and disposal facilities on low lying coastal marsh lands that occur primarily east of the Sabine River. Under these circumstances production and disposal-well sites would be accessible primarily by dredged canal. The generating plant and its attendant facilities would be constructed on a chenier ridge or natural levee if they were available. If not, a pad of made land constructed from dredge spoil would be necessary. Access to the generating facility would require dredging either a canal or dredging of material to support a road.

Substantial dredging would be required to open canals to move heavy equipment to and from drill sites and the generating facility and to construct and maintain pipelines.

3. The third scenario requires that production facilities be located offshore in estuaries, bays, lagoons, coastal lakes or the Gulf of Mexico. Under these circumstances production facilities may consist of a network of wells in the water body or of groups of directionally drilled wells that may

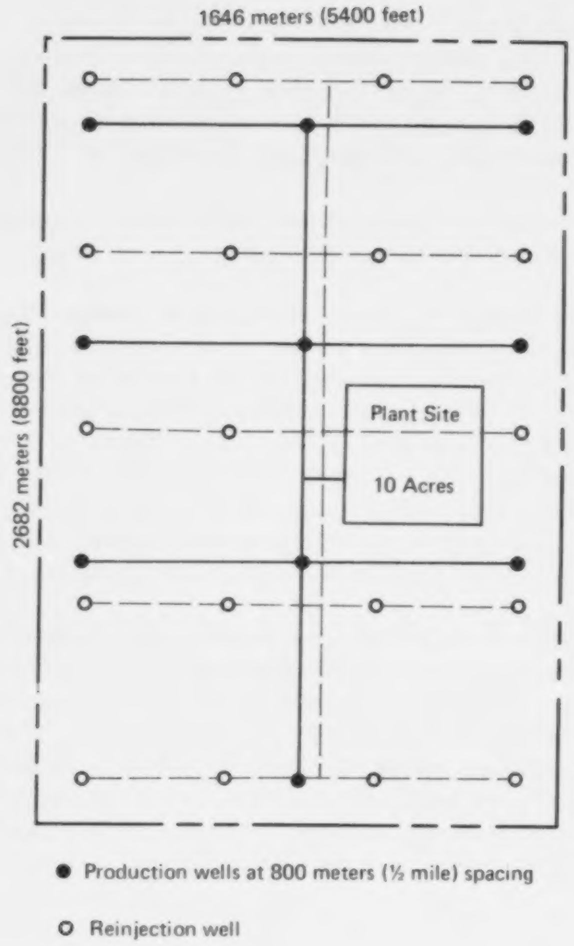

1646 meters (5400 feet)
2682 meters (8800 feet)
Plant Site
10 Acres
● Production wells at 800 meters (½ mile) spacing
○ Reinjection well

Figure 10. Plan of producing and disposal well sites (from Underhill and others, 1976)

be serviced from one or two production platforms.

In this case a gathering facility and the array of injection wells that constitute the disposal facility would still be located on land. A pipeline from the production wells to the generating plant site would have to be laid and, in part at least, the trench for the pipeline would have to be dredged.

POTENTIAL LOCATIONS OF ENERGY CONVERSION FACILITIES

At this time only one geopressured-geothermal test well site has been located (Bebout and others, 1976). This well site and any pilot plant or production facilities to follow would be located on flat low-lying Texas Coastal Plain about 6 miles east of Angleton, Brazoria County and approximately 15 miles inland from the Gulf of Mexico. Scenario I applies here. In Texas three other fairways may eventually be tested. Of these the Armstrong Ranch fairway lies about 30 miles inland from the Gulf of Mexico and scenario I also applies here. The remaining fairways occupy parts of Corpus Christi Bay, East Matagorda Bay, the Gulf of Mexico and adjacent land areas; for these areas scenarios I or II could apply depending on where the most favorable geothermal resource areas lie in the subsurface.

In Louisiana three prospect areas have been identified (figure 3). The prospect area in Cameron Parish lies within the coastal marshes (figure 58) and probably would be accessible by road, marsh buggy or canal. Scenarios I and II apply here. The prospects in Acadia and Calcasieu Parishes lie mostly in upland areas and Scenario I applies there.

ENERGY CONVERSION FACILITIES

Production Systems

Production of geopressured-geothermal fluids on the Texas-Louisiana Gulf Coast can be accomplished using technology currently available to the oil industry. Wells have been successfully drilled and completed to depths of 9174 meters (30,000 feet) in both normally pressured and geopressured areas. Furthermore, wells have been successfully completed in the offshore where water depths are several hundreds of feet. The fundamental difference between emplacement of geothermal field wells on land and in the offshore is that: (1) offshore wells would probably be directionally drilled from a platform and (2) geothermal fluids would be transported by a submerged pipeline to a generating plant onshore. In either case, the operation of the well is essentially the same. The following is a simplified description of a deep drilling operation (Podio and others, 1976).

> "The first step in drilling a deep geopressured-geothermal well is the selection of a specific drill site. Once a site has been selected, a drilling program is prepared, the well is "staked" by a surveyor, and a location is prepared for the drilling rig and other equipment necessary for the operation. If the location is remote, it may also be necessary to build access roads."
>
> "In accessible areas, such as Texas Gulf Coast Onshore, the rig and other bulky equipment are brought to the drill site by trucks. The well will be drilled with a rotary drilling rig which is a highly portable piece of equipment that will be dismantled at some previous location, transported to the present drill site and reassembled by experienced oilfield personnel. The entire operation from site preparation through drilling and completion of the well will be carried out by an assemblage of specialized contract firms and oilfield service companies..."

"Various equipment necessary for the drilling operation includes

1. the rotary drilling rig, which includes large diesel engines to rotate a heavy string of drill pipe during the drilling operation
2. rotary drill bits, to grind through the various layers of rock to be penetrated
3. drill pipe, comprised of 30' joints with threaded ends that are connected to form a "drill string" as the well is drilled."

"The commencing of actual drilling operations follows a procedure as described below."

"Conductor casing is driven to a depth of about 100'. Actual rotary drilling now begins with a hole being drilled to a depth of about 2500'. This hole is started by drilling out the inside of the conductor casing. This is accomplished by rotating drill pipe with a bit and gradually lowering the pipe as the bit grinds up the rock below. As the hole becomes deeper, the drilling crew adds additional joints of drill pipe to the drill string."

"During the drilling operation, a fluid mixture of water, clay, chemical and weight additives known as "drilling-mud" is pumped down the inside of the drill pipe. This fluid passes through openings in the bit at the bottom of the hole and returns to the surface outside the drill pipe. This fluid is almost constantly circulated down the drill pipe and up the open area outside the pipe and serves to cool the rotating drill bit, bring rock cuttings to the surface (thus keeping the hole clean), and seals off the rock formations already penetrated by the hole. The drilling mud is necessary to prevent hole cave-ins and, by its density, controls subsurface pressures, thus preventing entry of subsurface rock fluids into the hole which could result in a "blow-out" at the surface."

"The characteristics of the drilling fluid are constantly monitored at the surface. Rock cuttings are removed by a screening device and those cuttings are examined by wellsite geologists. Other equipment measures the gas content, if any, in the returning drilling mud. After the mud has been decontaminated at the surface, it is recirculated down the drill pipe and the "mud circulation cycle" is repeated."

"When the hole reaches a depth of about 2500', another string of casing called "surface-casing" is set inside the conductor casing. The surface casing serves to protect fresh water sands from contamination by the drilling fluid and provides additional protection from higher pressures to be encountered at greater depths. The space between the inside of the hole and the surface casing is filled with cement to anchor the casing and to prevent fluids from escaping to the surface. This is done by displacing cement down the casing and forcing it out the bottom of the casing and back to the surface much the same as the drilling mud is circulated. After the cement has been allowed to harden, drilling is resumed using a smaller diameter rotary bit. This size hole will be drilled to about 10,000' at which depth a string of casing, called "production-casing," will be run and cemented, utilizing essentially the same procedure as described for the surface casing."

"During the drilling operations, many rotary drilling bits will be used. Whenever a bit becomes worn and must be replaced, the entire string of drill pipe must be removed from the hole. The pipe is disconnected and racked in the derrick. After the bit has been replaced, the drill string is reassembled as it is returned to the hole and drilling is resumed. This process is called "round-trip" and is repeated many times in the drilling of a deep hole such as we are now considering."

"At various stages during drilling, prior to running casing and at total depth, the drill pipe is removed from the open hole and evaluation logs are run. These logs consist of the measurement of a number of parameters including spontaneous potential, resistivity, conductivity, sonic response, response to radioactivity, etc. of the various layers of rock and fluids penetrated. To measure these parameters, tools are run to the bottom of the open hole by wireline and slowly pulled back to the surface while the various responses are recorded by instruments at the surface. Data from these logs are essential to the evaluation of the types of rocks and formation fluids penetrated by drilling. Temperature data is also recorded during this operation."

"If the hole is determined to be worthy of a completion attempt after total depth has been reached, another string of smaller diameter casing will be run. This will consist of a "liner" run from the bottom of the hole and overlapping a portion of the protection casing and a connecting "tie-back

> string" run from the top of the liner to the surface. The liner will be cemented into the open hole and to the protection casing."
>
> "If a completion is to be attempted, the casing will be penetrated at various selected intervals and fluid will enter the casing and flow through a tubing string to the surface. In our geothermal wells, the last string of casing will serve as a tubing string. Pressures will be controlled at the surface by a set of high pressure valves attached to the casing, commonly called a christmas tree. A more detailed description of the completion procedure will be submitted later."
>
> "The entire operation described above could require as much as six months time to complete, depending on the total depth of the well and the overall drilling conditions encountered."

Figure 11 represents a schematic of a particular drilling rig.

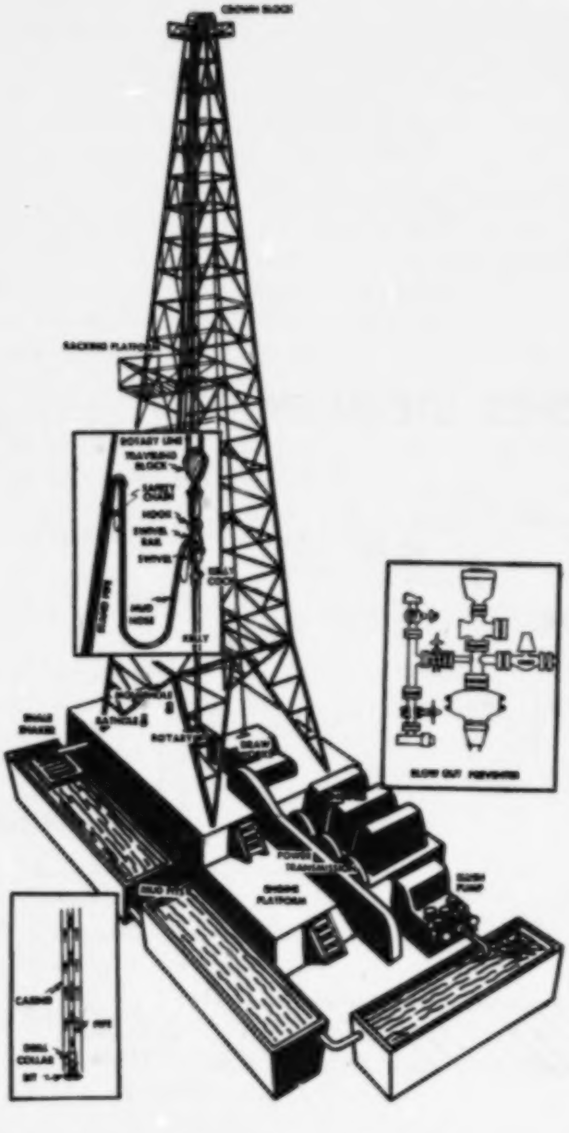
Produced fluids under pressure will be collected from the geopressured-geothermal well field and transported via pipeline to the power plant.

Generating Systems

For each location scenario, two possible power plant systems may apply: two-stage flashed steam and secondary working fluid systems. Wilson and others (1976) have suggested that approximately 10-12 production wells (at a flow rate of 6560 m^3/day (40,000 bbl/day) would be required to supply geothermal fluids to a 25-megawatt flash plant. Twenty to twenty-four injection wells with injection rates of 985 m^3/day (6,000 bbl/day) would be required to dispose of the spent geothermal fluids for a facility of this magnitude. At 1/2 mile spacings the well fields would require seven to ten square miles (figure 10). The plant site would require approximately 10 acres with additional acreage being required possibly for temporary holding ponds.

Preliminary conceptual designs and cost estimates have been prepared for the two most likely power plant types. The following power plant descriptions are from Underhill and others, 1976.

> "The two-stage flash steam plant receives its brine fuel from the fuel plant at 320°F and 2,000 psia, and at a flow rate of 4,986,000 lb_m/hr (figure 12). A hydraulic


CROWN BLOCK
RACKING PLATFORM
ROTARY LINE
TRAVELING BLOCK
SAFETY CHAIN
HOOK
SWIVEL BAR
SWIVEL
KELLY
ROTARY
SHALE SHAKER
POWER TRANSMISSION
ENGINE PLATFORM
SLUSH PUMP
MUD PITS
BLOW OUT PREVENTER
CASING
PIPE
DRILL COLLAR

Drilling rigs vary in size and in capacity, although the component parts remain the same and in about the same position. This rig illustrates the principal parts. The blowout preventer, out of its normal position beneath the rotary table, is shown with its many valves and rams necessary for protection against excessive formation pressures and unexpected well flows. The lower inset indicates the circulating fluid coming from the slush pump down through the drill pipe, out the bit and back up the hole. This fluid is returned to the surface, cleaned of sand and cuttings in the shale shaker, is allowed to settle until it reenters the cycle at the slush pump.

Figure 11. Drilling rig (Podio and others, 1976)

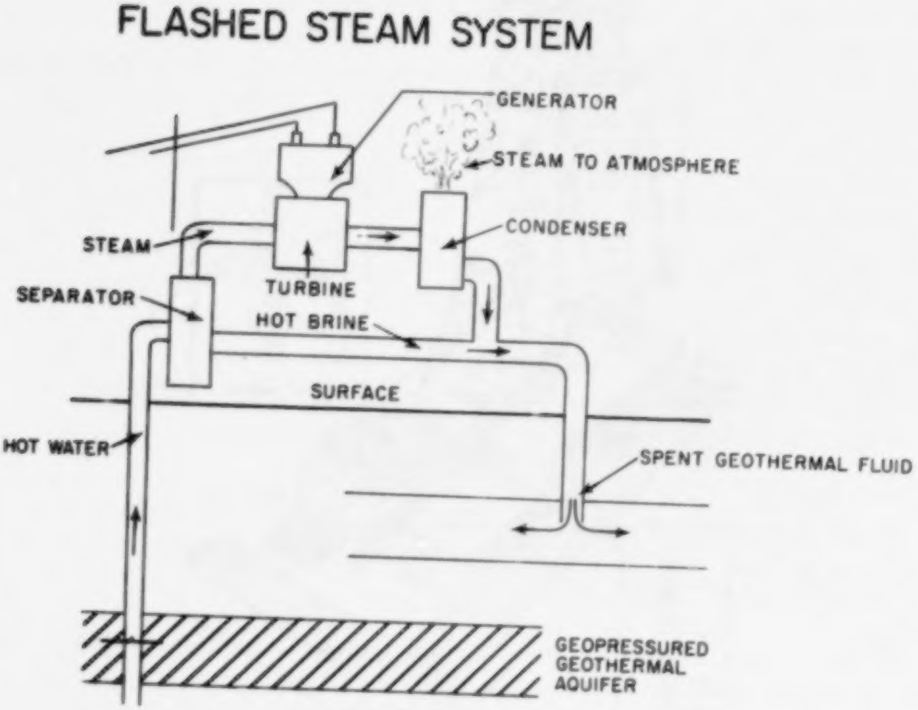

FLASHED STEAM SYSTEM
GENERATOR
STEAM TO ATMOSPHERE
CONDENSER
STEAM
TURBINE
SEPARATOR
HOT BRINE
SURFACE
HOT WATER
SPENT GEOTHERMAL FLUID
GEOPRESSURED GEOTHERMAL AQUIFER

Figure 12. (from General Accounting Office, 1975) turbine/generator set produces 5.13 MW(e) with a pressure drop of 1,700 psia. The turbine is assumed to have an efficiency of 80% and the generator an efficiency of 90%. Two methane separators, operating at 300 psia and 150 psia, respectively, then further reduce the pressure and extract most of the methane remaining in the brine (44% and 8% of total, respectively). Two flash chambers operating at 29.8 and 7.5 psia exit pressures, respectively, flash and demist steam for use in a double entry, single-stage steam turbine (20.8 MW[e]). The 29.8 psia, 1,164 Btu/lb_m steam passes into the inner entry while the 7.5 psia, 1,138 Btu/lb_m steam passes into the outer peripheral entry. Turbine exhaust conditions are 1.3 psia, 110°F, 1,051 Btu/lb_m. Turbine exhaust steam condenses in a surface heat exchanger operating at 1.3 psia with noncondensible gases (H_2S, methane, etc.) exhausted to atmosphere and flared (if flammable). No equipment was included for H_2S removal; should H_2S be present this will need to be added either in the form of a flare or an FeO_2/charcoal system."

"Heat rejection is via a mechanical-induced-draft evaporative type cooling tower with seven cells. The tower is designed to cool about 77,000 gpm of water from 110°F to 85°F (design load of 922,000,000 Btu/hr). Makeup to replace evaporation and windage losses is obtained from the condensate from the condenser."

"...flash steam plant requires 21% less well production. Thus, for a given reservoir, the risk of reservoir depletion before the plant is fully amortized is reduced accordingly ...."

"All brines produced from geothermal reservoirs will have to be disposed of in an environmentally acceptable manner. If subsurface disposal proves impossible or uneconomic, then considerable capital, operations, and maintenance costs could be incurred in surface disposal systems. Especially will this be so if non-flammable non-condensibles are present (H_2S, etc.). The presence of H_2S will require flash system effluent treatment and possibly cooling tower recirculation and blowdown treatment."

"Should subsidence prove a serious enough problem that total subsurface disposal is required to help provide compensation, then use of steam condensate for cooling tower makeup may be impossible. Then the local availability of makeup water for the evaporative cooling towers may become a key issue."

"The propane secondary working fluid plant (binary cycle system) receives its brine fuel from the fuel plant at 320°F and 300 psia at the rate of 7,960,000 lb_m/hr (figure 13). Two parallel banks of ten in-series heat exchangers, having 212,960 Ft^2 transfer surface, transfer 1,151,000,000 Btu/hr from the brine to the propane secondary fluid. Propane at 300°F and 900 psia passes from the vaporizers through a liquid knockout drum at the rate of 5,916,000 lb_m/hr and directly to the turbine. The turbine develops 55,300 shaft horsepower at 3,600 rpm with an efficiency of 75%. The associated generator develops 41.25 MW(e) at an efficiency of 90%."

"Superheated propane exits the turbine at 176°F and 221 psia and enters plate-type surface condensers having 1,076,000 Ft^2 transfer area and a load of 1,010,000,000 Btu/hr. A seven cell, mechanical-induced-draft cooling tower provides heat rejection to ambient conditions of 80°F wet-bulb temperatures. Cooling water from the condensers enters the tower at 105°F and is returned to the condensers at 90°F at the rate of 135,000 gpm. Propane leaves the condensers at 105°F and 201 psia and is returned to the vaporizers at 105°F 201 psia by passing through three feed booster pumps (586 SHP total) and two booster pumps (13,650 SHP total)."

"The power conversion cycle develops 41.25 MW (e) [gross], but a very large in-plant service load for the cooling towers, feed booster pumps, and main feed pumps reduces the plant output to 25 MW(e) [net]. The primary service power requirements are for the propane feed repressurization."

"Evaporative-type cooling towers appear to be ill-suited for heat rejection from secondary working fluid cycles. One might expect that an integral condenser/dry cooling tower design would be more compatible with the secondary fluid technology. Such a design would clearly be more compatible with the environment in water deficient regions as the South Texas Gulf Coast. Note, however, that ambient conditions would many times be unfavorable because of high summer temperatures. Some type of bottoming would be required to maintain plant efficiency in such conditions."

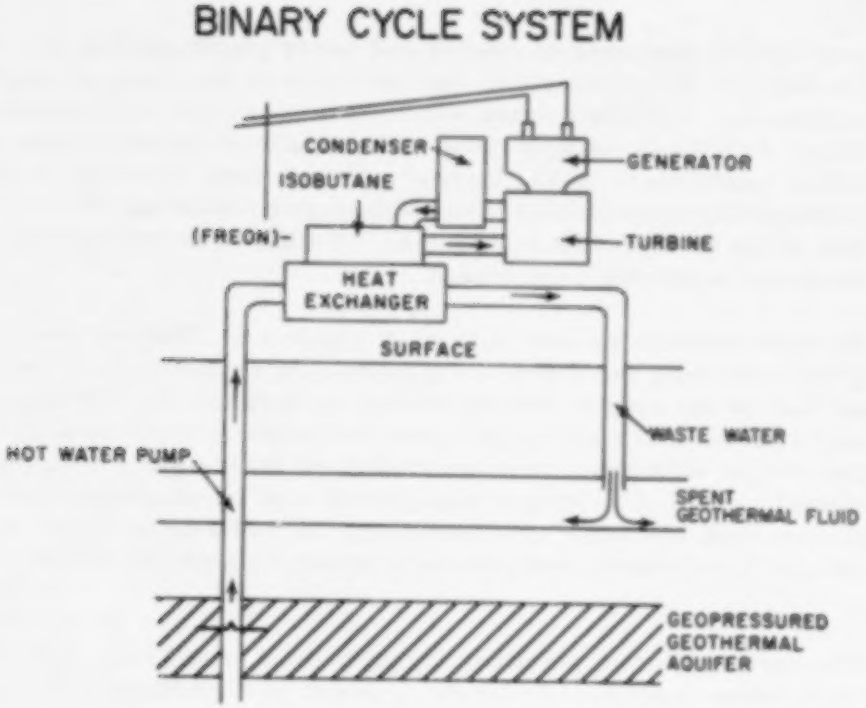

BINARY CYCLE SYSTEM
CONDENSER
ISOBUTANE
(FREON)
GENERATOR
TURBINE
HEAT EXCHANGER
SURFACE
WASTE WATER
HOT WATER PUMP
SPENT GEOTHERMAL FLUID
GEOPRESSURED GEOTHERMAL AQUIFER

Figure 13. (from General Accounting Office, 1975)

The fundamental difference between the flash method and secondary working fluid method (binary) in terms of environmental impact is that the flash method allows non-condensable gases to be passed to the atmosphere or flared if combustible.

A third system for generating power from hot-water fields has been proposed by the Atomic Energy Commission's Lawrence Livermore Laboratory. This system, still in the conceptual stage, uses the total-flow concept with hot geothermal fluids passing through a nozzle into a turbine (figure 14).

Pipelines

A system of pipelines to collect and carry geothermal fluids from production wells to the power plant site and later to the disposal facilities will be necessary. Collector pipes will have a diameter of 17 centimeters (7-1/2 inches) or less at the well head. The minimum expected pipe size would be 10.4 centimeters (4-1/2 inches). Trunk lines that feed geothermal waters to the power plant will be somewhat larger depending on the number of collector pipes feeding into a trunk line. Pipelines from production wells will be insulated to prevent heat loss.

Current practice on land is to bury pipelines. Shallow trenches are dug, slightly exceeding the width of the pipe; pipe sections are welded together and laid in the trench; and the trench is back filled. Pipelines are constructed to pass under minor streams and roads and are usually carried over major rivers at bridges or suspended from cables and piers. The environmental impact of burying a pipeline on land is relatively minor, consisting of disturbed soil and vegetation along the route of the pipeline. Vegetation can be reestablished generally along the pipeline within a few months.

The construction of pipelines through wet lands, bays, estuaries, or the Gulf of Mexico, however, is likely to result in significant local environmental impacts (McGinnis and others, 1972). Major impacts will result from loss of habitat and vegetation in areas occupied by spoil piles, levees and the canal. Reduction of water quality will probably result from the redistribution of heavy metals, pesticides, sulfides and particulate matter contained in the dredged spoil. Canals and levees serve to interrupt natural drainage of marsh areas and can locally raise or lower water levels.

McGinnis and others (1972) have described the construction methods for laying pipelines in marshes.

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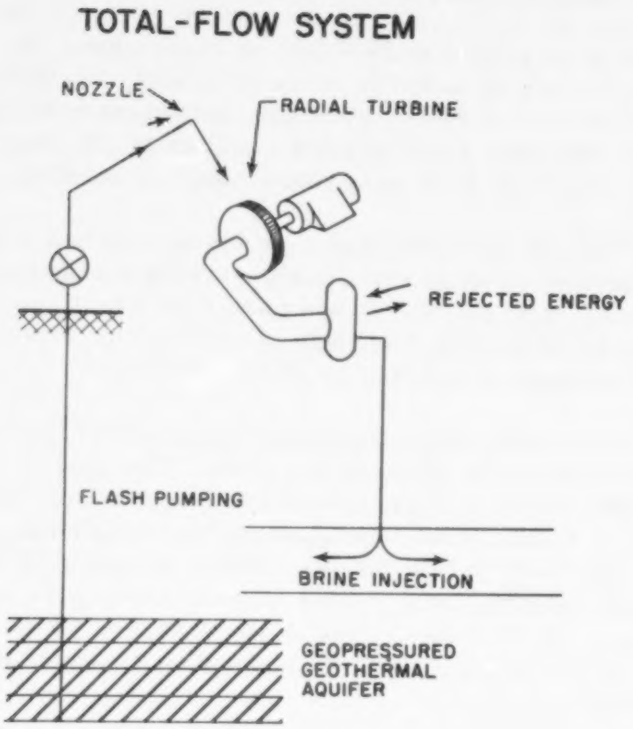

TOTAL-FLOW SYSTEM
NOZZLE
RADIAL TURBINE
REJECTED ENERGY
FLASH PUMPING
BRINE INJECTION
GEOPRESSURED GEOTHERMAL AQUIFER

Figure 14. (from General Accounting Office, 1975) relatively shallow ditch is excavated by a dragline or clamshell digger from the bank. By using a marsh buggy base or by using runners or pads to spread the weight, the damage to the bank is minimized. The ditch may be 4 to 6 ft deep by 8 to 10 ft wide. The pipe sections are joined together at the point of origin of the ditch, the line given temporary buoyancy by strapped floats, and pushed or shoved down the ditch. A section as much as 15 miles long can be installed in this fashion. After being floated into place the floats are cut loose and the line allowed to sink to the bottom of the ditch. Typically, there will be approximately 4 feet of water above the pipe. The ditch may be left open but is more frequently backfilled. Even with firm marsh, there is generally sufficient subsidence and shrinkage that the spoils will not completely fill the ditch. However, there usually is no canal after completion. . . . "

"The second method of pipe laying utilizes a flotation canal to provide access for the pipe-laying equipement. Such a canal may be 40 to 50 feet wide and 6 to 8 feet deep, and may have an additional trench in the bottom to provide 10 to 12 feet clearance above the top of the pipeline."

"The pipeline is constructed on a series of lay barges and passed over the stern of the train. The pipe is large and heavy, and massive equipment is needed to manipulate it. For example, a standard 40-ft section of 36-inch-diameter pipe weights approximately 8,000 lb. After the addition of a corrosion coating and 3 to 4 inches of concrete to give it negative buoyancy, a 40-ft section weighs about 34,000 pounds. Equipment to handle weights of this magnitude cannot be supported by the marsh."

"This type of canal is excavated by a flotation dredge, which normally piles the spoils upon each side to form a low levee. Characteristically, where this type of canaling is carried on, the marshes are soft and unstable, sometimes to the point of being near-floating marshes."

"Generally, the spoils are piled back some distance from the canal to leave a 30 to 40-foot berm between the canal and the levee. The levees are characteristically low and flat. Depending upon the width and depth of the canal (which determines the quantity of the spoils) and on their stability, a levee may be 3 to 5 feet high and possess a base width of 50 to 85 feet. The high water content (50-80 percent) and the organic nature of the excavated muck leads to major shrinkage and subsidence when piled on top of marshland with similar properties. Height reductions of 50 percent are possible. The paramount factor in the permanence of a levee is the type of marsh upon which the levee is placed. The condition of the marsh at the time the levee is placed is of great importance. When water is over the marsh the surface material is supersaturated and becomes very weak and almost fluid. Poorly shaped levees which spread across the marsh result from this condition. Because of these factors, there are never enough spoils from the excavation to backfill a flotation canal."

"In the past, levees were characteristically continuous, with few or no breaks. More recently, the Louisiana Wildlife and Fisheries Commission has required openings to be cut in levees in order to minimize disturbances to existing drainage and use patterns."

"In the course of laying such a line through marshland, numerous bodies of open water will also be traversed. The same equipment may be used, although only a trench will be dredged, or the assembled line can be jetted into place. Hydraulic dredges are also used for open water traverses. Hydraulic dredge spoils may be pumped to nearby land, dispersed over the nearby area, or piled up in a spoil island, depending on the particular situation."

"Treatment of completed canals, whether "push" or "flotation" is a matter of negotiation between the pipeline owner and the owner of the land being traversed. Land owners may require bulkheads or plugs or dams wherever a canal intersects another waterway, in order to minimize erosion and to prevent navigation traffic, which is a prime cause of erosion."

Disposal Systems

In recent years three methods of disposal of saline waters have been practiced along the Gulf Coast. The Frasch sulfur industry currently disposes of its saline process fluids into adjacent saline water bodies or it discharges them into fresh-water streams during periods of high discharge. The volume of these process fluids may exceed 22,950 m^3/day (140,000 bbl/day). Prior to 1969, brines produced as by-products with oil and gas, were disposed of by the oil industry in large evaporating pits in many localities. Brines produced currently with oil and gas are injected, either into the peripheral areas of the producing reservoir, or into a suitable saline aquifer.

Federal and Texas regulations that apply to surface disposal and temporary surface storage of geothermal fluids in Texas are summarized in Gustavson and Kreitler (1976) and are discussed in detail by Rogers and Overbeck (unpublished manuscript, 1977). Under current regulations it appears that the disposal of suitably treated geothermal fluids into surface waters could be permitted. Temporary storage of spent geothermal fluids may also be permitted.

Disposal into surface waters would be by a pipeline exposed near the bottom of a water body and fitted with a device to cause rapid and effective mixing with ambient waters. Disposal of large volumes of brine into surface waters or temporary storage in holding ponds is, however, likely to result in significant environmental impacts. Gustavson and Kreitler (1976) describe the impact to Chiltipin Creek of salts that are apparently the residual of evaporated oil field brines. Salinity of Chiltipin Creek waters have exceeded 35,000 ppm several times a year since 1969. Underhill and others (1976) list numerous potential problems associated with surface disposal:

(1) Total quantity of fluids produced daily.

(2) Salinity of fluids and protection of potable water supplies.

(3) Requirements for surge protection -
    (a) Pipeline system emergency shutdown.
    (b) Utilization system bypass.

(4) Noxious or poisonous gases removal or conversion.

(5) Dissolved or entrained oxygen prevention or mitigation; corrosion control.

(6) Solids removal and/or disposition control.

(7) Thermal transient prevention or mitigation.

(8) Thermal content of fluids and thermal enrichment to environment near point of disposal.

(9) Entrained and dissolved solids removal before fluid disposal.

(10) Creation of appropriate fluid mixing zones to eliminate stratification and other effects in the recipient water body.

(11) Maximum salinity and temperature deviations from natural salinity and temperature environment of receiving water body.

(12) Pipeline leakage detection.

(13) Mitigation of subsidence or seismic event effects upon disposal system integrity.

(14) Optimization of economics and energetic impacts of facility.

(15) Maximum economic distance from utilization facility to disposal point.

(16) Impact of topographic features and soil conditions upon design and economics of disposal system.

(17) Impact of pipeline upon environment.

(18) Impact of permitting process and regulations upon design and economics of disposal system.

Underhill and others (1976) suggest that these problems have not been systematically studied. The literature review that we have recently completed also indicates that systematic studies of the problems that could arise from surface disposal of high volumes of high temperature brines are not generally available.

Disposal of geothermal fluids into the subsurface will result in substantially less impact to the environment than would surface disposal. Reinjection of oil field brines has been common practice of the Texas oil industry for many years. Along the Gulf Coast large volumes of oil field brines are reinjected to depths of 305 to 2,134 meters (1,000-7,000 feet) at pump pressures ranging from atmospheric pressure to 170 kg/cm^2 (2,400 psi) and at rates of 12.2 to 1,640 m^3/day (75 to 10,000 bbl/day) (Texas Railroad Commission, 1975). Underhill and others (1976) in their discussion of the disposal of geothermal fluids present opinions of two specialist organizations concerning the potential for subsurface disposal of large volumes of brines along the Texas Gulf Coast. One suggested that disposal rates of 3,280 m^3/day (20,000 bbl/day) may be possible in a 1,524 to 1,829 meter (5,000 to 6,000 foot) well. The second suggested that a disposal rate of 5,740 m^3/day (35,000 bbl/day) may be possible in a 1,524 to 1,829 meter well. Actual disposal rates would depend on the porosity, permeability and geometry of the sandstone body or bodies into which the spent geothermal fluids will be pumped.

Twenty to twenty-four injection wells may be needed to dispose of the 64,800 m^3 (400,000 bbl) of spent fluid from a single 25 megawatt power-plant: the number of wells is dependent upon the rate of disposal per well. Disposal wells, 1524 to 1829 meters deep will be cased to just above the stratigraphic units that will receive the waste fluids. The casing will be cemented off to protect fresh water sands and shallow oil and gas, if any.

Spent geothermal fluids will retain salinities that lie within the range of salinities that are normal for formation waters of the Gulf Coast, and the distribution of dissolved ions will approximate the chemical profile of formation waters. At temperatures of less than 71°C (160°F) (temperature on leaving power plant) spent geothermal fluids are likely to be only a few tenths of a degree hotter than formation fluids at depths of 1524 to 1829 meters. Consequently, in the absence of an accidental release of brines, the only remotely possible major impact resulting from the reinjection of geothermal brines would be an upward migration of the base of fresh ground water that would overlie the area of the disposal field. Fresh ground water will be separated from injected geothermal fluids by several thousand feet of sediment, sediment that will include many largely impermeable beds of mudstone. Furthermore, geothermal fluids are not likely to mix with the fluids of the sediments into which they are injected; geothermal fluids will most likely push the original formation water away from the injection well borehole. In presently operating disposal wells--wells that are not injecting brines into oil and gas reservoirs--the eventual disposition of the displaced original formation water is unknown. The disposition of formation waters to be displaced by the injection of geothermal fluids is also unknown. A system of monitoring wells could document the movement of geothermal waste fluids through the rock column and could document the position of the base of the fresh ground water zone.

PREDICTABLE ACCIDENTS OR FAILURES OF PRODUCTION, GENERATING, OR DISPOSAL SYSTEMS

From the complex network of production wells, pipelines, power plant, and disposal wells that will comprise a geopressured-geothermal electrical generating plant an accidental release of hot brines is, at least remotely, possible. The times when this is most likely to happen is in the process of drilling the well--a blow out--, during normal maintenance procedures of an operating well, or as a breech in the pipeline that will carry the geothermal water from production well to generators to disposal well.

Blowouts are most likely to occur when gas or water is allowed to flow into the drill hole at depth and to dilute the drilling mud during initial drilling of the well or during normal maintenance. If the weight of the column of drilling mud is insufficient to prevent formation fluids from entering the hole, the drilling mud is diluted and displaced by formation fluids. Normally this process can be controlled by increasing the weight of the drilling mud. Stuart (1970) describes both the types of problems that have been encountered in drilling into geopressured sediments and the technology that has been developed to overcome these problems. If the flux of water or gas into the well cannot be immediately controlled by increasing the weight of the drilling mud, the well must then be closed off. This is accomplished by closing a series of hydraulic rams located under the floor of the drill rig (figure 11), called blowout preventors. The blowout preventors may also be closed manually. When the blowout preventors are closed, they stop circulation of drilling mud and formation fluids between the drill pipe and the surrounding rock; circulation of mud on the inside of the pipe is controlled by the mud circulation pump. In extreme cases blind rams can be closed that will collapse or shear through the drill pipe and close off the hole. With the blowout preventors in place drilling mud weight can be increased and control of the well reestablished.

Blowouts can also occur during normal maintenance of a well throughout its operating life. If blowout preventors are used during maintenance the same procedures that are used during drilling operations can be followed to control blowout.

Accidental breaks or leaks in the pipeline transporting geothermal fluids are also possible. The potential for pipeline breaks will be much diminished if the pipelines are buried. Spills or leaks can be controlled in several manners. Chokes placed within the production well will automatically close off the well if a rapid pressure drop occurs as a result of a pipeline break or equipment malfunction. Pressure gauges in the pipeline will automatically activate gates or valves in the pipeline to prevent loss of geothermal fluids in the event of a pipeline break or leak.

In the event of pipeline breaks or leaks or of equipment malfunction in the power plant it may be necessary to temporarily store geothermal fluids in surface holding ponds adjacent to the power plant site. Holding ponds will be lined with impervious material to prevent leakage and contamination of shallow ground water.

For offshore wells that have been drilled in the Gulf of Mexico blowouts have occurred at a rate of one for every 245 wells that have been drilled (Bureau of Land Management, 1977). In the blowouts that have occurred since 1971, none has released more than 33 m^3 (200 bbls) of oil to the environment. Since 1967, 26 pipeline breaks have resulted from anchor dragging and internal corrosion of pipelines. If the development of geopressured-geothermal resources occurs in the offshore accidental releases of geothermal fluids can probably be expected to occur at these rates or less frequently if technology improvements occur.

POTENTIAL ENVIRONMENTAL INTRUSIONS

Site Development

Intense development will occur only at the power plant site where the construction of roads, temporary holding ponds, power transmission lines and the power plant will require the use of a minimum of 10 acres. The major impact here is that the area of the development site is withdrawn from the natural system. Disposal and production wells will be serviced by a network of unimproved dirt roads whose impact on upland area environments will be minor. The construction of roads or canals in wetland areas would, however, be a severe impact on the local environment. With modern technology and proper management, well sites in upland areas will constitute only a very minor impact to the local environment. In wetland areas, however, well sites established on dredged material will constitute severe local impacts to the environment, mainly due to the process of dredging as discussed previously.

Subsidence and Faulting

The utilization of geopressured-geothermal resources requires the withdrawal of enormous volumes of geothermal fluids from the subsurface. It is probable that fluid withdrawal from aquifer sandstones in the geopressured system will allow fluids from adjacent mudstones to flow into the sandstone aquifers as a pressure gradient is established. This induced dewatering of geopressured mudstones will probably allow a certain amount of compaction of the mudstones to take place, and transmittal of the compaction to the surface may result in subsidence (see Gustavson and Kreitler, 1976 for a discussion of compaction and subsidence models). The impact of subsidence in undeveloped upland areas will probably be minor. Subsidence in or near wetlands could result in a significant environmental impact in that slight changes in land elevation can result in extensive lateral shifts in wetland vegetation zones.

Active faulting on the Gulf Coast has been recognized in several areas and, in part at least, fault planes may control or limit subsidence (Gustavson and Kreitler, 1976). This is not to say that the Gulf Coastal Plain of Texas and Louisiana is a seismically active area. Recent fault movement has been documented by Kreitler (1976), but the movement has apparently been too local and too slow to generate seismic shocks. Major impacts resulting from fault movement has been damage to structures such as pipelines, roads, buildings.

Drilling fluids and rock cuttings disposal

For each well drilled a column of rock material equal to the depth of the well and several inches in diameter will be removed. For a 3660 meter (12,000 foot) well with an average diameter of ten inches this will be 185 m^3 (6,500 cubic feet) of rock; enough to fill a large room. Rock cuttings are disposed of by burial in upland areas. Cuttings from offshore wells or from wells in wetland areas must be returned to dry land areas for proper disposal.

Drilling muds are a variety of water-or oil-base fluids with additives that are used as lubricants in well drilling. Not only do drilling muds serve to lubricate and cool the drill bit but they remove rock cuttings from the bottom of the hole and carry them to the surface. Properly prepared muds prevent formation fluids from entering the drill hole and also prevent large quantities of drilling mud from flowing into drilled formations.

Drilling muds can contain a variety of toxic substances, including for example, caustic soda and diesel oil. Therefore, muds must be properly contained during use and properly disposed of to minimize environmental impact. Drilling muds are relatively expensive (Podio and others, 1976) and under some circumstances can be stored and reused. Since disposal is often by burial in shallow pits, reuse is preferable not only because it is economical but because it reduces the potential impact to the environment.

Drilling muds to be disposed of from offshore wells and from wells drilled in wetlands are usually removed to disposal sites on dry land areas.

Noise

The development of geopressured-geothermal resources under all three scenarios will result in similar elevated noise levels. Temporary noise level increases will result from the construction of each drill site and from well drilling. The drilling operation involving the use of heavy equipment and large diesel engines occurs 24-hours a day for several weeks or longer and noise levels of 80 to 90 dBA can be expected (Neilson and others, 1976). The construction of pipelines and the power plant will also result in local temporarily increased noise levels largely due to the operation of construction equipment.

Once the entire facility is in operation noise from pipelines and production well sites will be largely eliminated. Pipelines will be buried and fluid production wells will be driven by geopressure. Steam will not be vented from wells and pipelines as it is in certain hydrothermal-geothermal areas.

In reinjection of the spent geothermal fluids a portion of the original pressure will be retained in the pipelines supplying disposal wells. This residual pressure may be sufficient to reinject spent geothermal fluids. If, on the other hand, additional pressure is required to drive disposal fluids into receiving rock units, then pumps would be required. Pumps for disposal wells would increase noise levels locally for the life of the field.

At the power plant site, the noise level will be increased throughout the life of the field. The major noise sources are the generators and cooling towers. If the secondary working fluid (binary) system is used geothermal steam would not be vented. Other systems allow the venting of certain amounts of steam resulting in additional noise levels.

Ambient noise levels for a geopressured-geothermal field site would probably be similar to those of a hydrothermal geothermal field, in the range of 40 dBA (Neilson and others, 1976). This is not substantially different from natural noise levels along the Gulf (Federal Energy Administration, 1976). However, if it proved necessary to release geothermal fluids to holding ponds or as steam noise levels could increase temporarily to substantial levels 90-100 dBA at 15.2 meters (50 feet) from the noise source.

POTENTIAL WASTE PRODUCTS

Geothermal Fluids

Conversion of geothermal energy to electrical energy may yield waste products that will impact several sectors of the environment. Although only limited data is available on the chemical composition of product geopressured-geothermal waters general knowledge of concentrations and distributions of ions is available (figure 9). Possible air contaminants derived from the release of geothermal fluids are water vapor, methane (CH_4), non-methane hydrocarbons (C_NH_N), hydrogen sulphide (H_2S), boric acid (H_2BO_4) and ammonia (NH_3) (Kharaka, and others, 1977). If extracted hydrocarbon residues are burned, other carbon compounds may be released to the atmosphere. Water vapor from cooling towers may contribute to increased fog in the immediate area of the power plant.

Harder, Whitman, and Rogers (1965) have observed substantial natural methane production from the coastal marshes of Louisiana produced by bacterial action or organic matter. Methane in geothermal fluids will be removed by gas separators. The residual methane that could be released from water vapor at cooling tower would be slight and possibly not significant compared to natural concentrations in the atmosphere.

Non-methane hydrocarbons, hydrocarbons, hydrogen sulphide, boric acid and ammonia occur in some geothermal liquids and could be released to the atmosphere along with water vapor from cooling towers serving flash steam plants. Other sources of air contamination will be evaporation from storage ponds and emission from supporting diesel and gasoline powered equipment.

The impact of geothermal fluids depends on the manner in which they are disposed. In the marshlands and estuary systems of the coastal zone, a delicately balanced broad mixing gradation of fresh to salt water exists and direct disposal or accidental, release into surface waters can have a number of significant negative impacts. Mixing occurs as fresh water discharge from streams intermingles with oceanic waters moving landward through tidal inlets and passes, and by storm inundation. The primary effects will be the degradation of vegetation and aquatic fauna intolerant to quick salinity or temperature changes resulting from geothermal fluid releases. In addition, boron contained in geothermal waters may be sufficient to produce harmful effects on vegetation. Release of saline geothermal fluids on land would impact vegetation and temporarily increase soil salinity. Sustained releases on land could increase soil salinity to the point where the soil would no longer support vegetation.

Estuarine and marsh ecosystems represent the most biologically productive area on the coast. . . "Not only are they the foundation of the fishing industry, but they provide important habitats for migratory fowl, fur-bearing animals, and reptiles, and are important scenic recreation areas", Gagliano and others (1972), p. 76. Protection of surface water and salinity regimes are of prime importance in conserving coastal area.

Contamination of fresh ground water can occur in two fashions: contamination of shallow ground water from the release of geothermal fluids at the surface and contamination of deep ground water by intrusion or updip migration of saline ground water driven by disposal wells.

Because of its potential impacts on air and ground water quality, disposal of geothermal fluids will be regulated and closely monitored by the Texas Air Control Board, Louisiana Air Control Commission, Texas Water Quality Board, Louisiana Department of Conservation and the Texas Railroad Commission.

Cooling Tower Fluids

Many methods of condenser cooling are possible in the coastal region either by a running ground water or stream system, by continuous recirculation from cooling ponds, or by mechanical draft towers. Each of these methods employs treatments or induces some chemical and physical effects on the cooling waters. Rivers and streams are numerous all along the northern coast of Texas and Louisiana as well as water circulating through canals. Surface water and ground water is, however, scarce along the southern coast of Texas.

Chlorine may be added to prevent fouling of condensers by untreated natural waters. In geothermal plants using natural flow type cooling from coastal streams, this will directly impact normally occurring biota. Additional algecides, biocides and corrosion and scaling inhibitors are added to recirculating cooling systems and these chemicals can become concentrated by evaporation in draft towers or holding ponds. Furthermore, these cooling fluid additives are carried into the atmosphere and to the surrounding landscape in water vapor droplets.

Heat Energy

Pipelines leading from production wells to the power plant will be insulated to conserve heat energy. Heat energy is conserved for all types of generating systems to the point where the working fluid is used to drive the generator. As the working fluid leaves the turbine the working fluid must be condensed and cooled. Waste heat is passed off to the atmosphere primarily at the cooling towers.

The inefficient utilization of total generated energy is a major factor in economic energy production and is a contributing source to energy shortages as a whole. Operating thermal efficiencies in most types of generating facilities today is less than 50 percent (Limberg, 1974). Most of this energy is lost or dissipated as low-grade waste heat additions into the environment.

The impacts of geothermal heat discharge into the atmosphere and surface waters of Texas and Louisiana is of much concern. The discharge of heat to a body of water can cause various physical, biological and chemical effects, however the greatest impact will be on the aquatic ecological system. "As water temperature is raised, the oxygen holding capacity of the water decreases, the recreation rate rises, density changes may cause stratification, evaporation is increased, chemical, biological, and physical reactions tend to be at a faster rate, and viscosity decreases, which reduces the sediment transporting ability of the water." (Rimberg, 1974, p. 38). Overall, the changes that the addition of heat create are largely dependent on natural characteristics of the water body and kind of utilization of the water body by man. Surface waters of the Texas-Louisiana coast cover a whole spectrum of different types of water bodies and water chemistries from open marine to fresh water pond, in arid to semi-tropical environments. If surface waters are used in a cooling system or for disposal of geothermal waters, effects of geothermal heat discharge will be dependent on plant site location and proximity to and use of water bodies.

In the geothermal plant system, there are several processes in which heat energy will escape into the atmosphere by water vapor or convective heat transfer. Measurable climatic modifications from the release of heat and materials include increases in mean air temperature, precipitation, and cloud cover, in addition to changes in opacity of the atmosphere (Rimberg 1974, p. 31).

Sewage and Refuse

During normal operations of well drilling, plant construction and operation and pipeline construction, refuse, including human waste and garbage, will be generated. The impact from improper disposal of sewage and refuse is both unaesthetic and physical; the major physical impact being potential contamination of shallow ground waters and surface waters. Refuse from offshore and onland drilling sites and from construction sites is usually contained and removed for disposal. Human wastes and garbage will probably be disposed of into septic tanks and leach fields, if possible. If use of a septic tank is not possible waste and garbage will be treated before on site disposal or contained and removed for proper disposal.

ALTERNATIVE USE OF WASTE GEOTHERMAL HEAT

Increased efficiency and overall conservation of energy can be attained by the utilization of low-grade heat as a by-product rather than a waste product. Much research has been done on usage alternatives of moderate temperature water and several people have researched and compiled the number of various industries in the study area who have a need or at least have processes within their industry that can utilize low-grade heated waters. Underhill and others (1976) have made a comprehensive survey of areas around Texas geothermal fairways as well as studying possible beneficiation of low-grade heat, and Hornburg and Morin (1975) outline specific processes in the manufacture of pulp and paper, and sugar cane refining along the Texas-Louisiana coast. In addition, much work has been done on evaluating the different levels of low-grade heat for different processes which implies that the water can go through several stages of use or be used by several different users. In most instances planning the use of geothermal waters for new industries is more economically feasible than conversion of the old. As geothermal energy plants are developed, new industries will ultimately situate as near as possible to the energy source. Early planning can make it possible for industries and communities which can utilize several grades of low heat energy as well as electricity generation to be situated so as to obtain the highest use of geothermal water.

SUMMARY

Geopressured-geothermal resources of the Gulf Coast of Texas and Louisiana are currently being evaluated as thermal-hydraulic energy sources to drive turbines to generate electrical power. Gulf Coast geothermal fluids are brines with salinities generally in excess of 40,000 ppm and temperatures up to 283°C (520°F). The proportions of dissolved ions in geothermal fluids is markedly different than that of sea water, and the fluids are expected to be saturated with methane. As much as 54,000 m^3 (310,000 bbls) of fluids per day at a temperature of 300°F will be required to feed one 25 megawatt power plant.

There are three possible location scenarios for the development of geopressured-geothermal resources: (1) production, generating and disposal facilities are on upland areas, (2) production, generating, and disposal facilities are on coastal wetlands and, (3) production facilities are offshore with generating and disposal facilities on land. Production and pipeline systems will follow closely the current methodology and technology of oil and gas well drilling. Generating systems will probably utilize a one-or two-stage flash steam system or a secondary working fluid system. The secondary working fluid system is advantageous in that geothermal fluids are wholly contained and not released to the environment. Disposal of geothermal fluids will be via injection in moderately deep, (1524 to 2134 meters) saline aquifers.

Serious environmental intrusions may result from geopressured-geothermal resource development. Impacts resulting from site development will be largely due to excavation of pipelines and construction of the power plant and holding ponds. The severity of these impacts will be greatest if development occurs in wetland areas.

Withdrawal of large amounts of fluids from the subsurface may induce subsidence and surface faulting. Subsidence will most seriously impact low lying urban areas, wetlands or coastal areas.

Waste products attributable to geothermal energy development include spent geothermal fluids, cooling tower fluids, waste heat energy and sewage. Spent geothermal fluids will be reinjected and the major potential impact is contamination of fresh ground water resources.

If residual methane, other heavier hydrocarbons, hydrogen sulphide, ammonia, and boric acid occur in geothermal fluids they may be released to the atmosphere along with water vapor at cooling towers. Waste cooling tower fluids will contain algacides, herbicides and corrosion preventors; all detrimental to the surface environment. Waste heat energy will be passed to the atmosphere along with water vapor.

Predictable accidents are blowouts of the production wells during drilling or normal maintenance or rupture of the pipelines that will carry geothermal fluids from production wells to power plant and back to disposal wells.

PHASE II

ABSTRACT

This research program was initiated to provide an estimate of potential environmental effects arising from the exploitation of geopressured-geothermal resources on the Gulf Coast of Texas and Louisiana. This portion of the project describes the ecological resource and potential environmental impacts.

The report contains a review of available information on fish and wildlife resources in areas proposed for geothermal exploitation. Physical and biological resources are summarized. Features that may be influenced or affected by geopressured energy activities are highlighted. Potential environmental impacts arising from the exploitation of geothermal energy on the Gulf Coast will vary with the location of the site, with the scale of industrial operations, with the type of generating and disposal systems employed, and with various management practices.

Processes and fluctuations among physical, chemical, and biological ecosystem components are emphasized in order to provide a baseline enabling identification of critical requirements for maintaining ecosystem productivity and integrity. Evaluation of potential environmental impacts relating to this resource is based on technical information presented in Phase I of this project.

This report was submitted in partial fulfillment of Contract No. 14-16-0008-2141 by the Bureau of Economic Geology, The University of Texas at Austin. The report covers the period from October 1, 1976 to June 1, 1977 and work was completed as of May, 1978.

INTRODUCTION

Potential exploitation of geopressured-geothermal energy resources along the Gulf Coast of Louisiana and Texas has resulted in concern for possible environmental impacts. As an initial step in assessment of the effects of such geothermal projects, the U.S. Fish and Wildlife Service, U.S. Department of the Interior has recognized a need for review of information concerning fish and wildlife resources of areas where geothermal exploitation might occur and how they might be affected by geothermal activities.

This study is not an environmental impact statement. It is intended to be a preliminary examination of both the biological resources of the coastal zone of Louisiana and Texas and some potential problems which might result from exploitation of geopressured-geothermal resources. The study represents nine months of effort directed mainly at surveying the literature available on topics of concern. A number of files relevant to the study have been assembled which are not presented in the report. These data will be available for future reference at the Bureau of Economic Geology, the University of Texas at Austin.

PURPOSE

The ecological resource phase (Phase II) of this project is a summary of biological resources of coastal Louisiana and Texas which might be affected by the exploitation of geopressured-geothermal energy; it also identifies potential ecological effects which might result from geothermal energy activities.

The assessment of potential impacts of exploitation of geothermal resources necessitates consideration of physical and biological environments of the region. Particular attention is given to ecological features that may either influence or be affected by geopressured energy activities. Major emphasis is placed on identification of unique ecosystem features including populations of producer, consumer, and decomposer organisms which may be threatened.

In this report the term Gulf Coast refers to marine and terrestrial areas adjacent to the coastlines of Texas and Louisiana.

PROJECT DESCRIPTION

Several potential impacts to fish and wildlife resources have been recognized based on analysis of information on the ecosystems concerned and the potential nature and extent of commercial exploitation of the geothermal resource. This evaluation considers the technical scenarios presented in Phase I and attempts to distinguish between potential new stresses from geothermal activities and stresses from other sources, both man-induced and "natural." Such stresses include whole organism and biological community responses to normal environmental regimes and altered responses to stressed regimes. Emphasis on processes and fluctuations among physical, chemical, and biological ecosystem components is intended to provide a baseline that will enable identification of critical requirements for maintaining ecosystem productivity and integrity.

Three major biological issues are addressed which are pertinent to impacts on fish and wildlife: 1) the adequacy of baseline data on kinds and quantities of organisms and on physical, chemical and geological features of the Gulf Coast region; 2) the status of predicting and identifying changes in ecological and physiological functions and processes anticipated from stress effects of geothermal exploitation; and 3) organismic, population, community, and ecosystem effects induced by such stresses.

The coastal region considered here includes approximately two counties or parishes inland along the Gulf Coast from the Mexican border to the Mississippi River and the near shore waters of the Gulf of Mexico. An extensive, although not comprehensive review has been made of published and unpublished sources concerning fish and wildlife of the study area. Alternatives and other mitigation options which might avoid or minimize geopressured energy impacts on fish and other wildlife are considered. Areas for which further research is needed have been noted and selected annotated bibliographies have been compiled related to the subjects of the study including endangered species of plants and animals of the region. A list of scientists and/or institutions, cross-indexed by relevent subject matter, is included for future consultation by others studying these issues.

Environmental effects of exploitation of geopressured resources may be localized if spent geothermal fluids are disposed of by deep well injection (See Phase I). Major constraints on such exploitation may be environmental impacts that could result from land subsidence, from surface disposal of brines if injection is not possible, or from accidental spills.

OVERVIEW OF THE TEXAS-LOUISIANA REGION

The coastal region of Louisiana and Texas is ecologically diverse and complex, perhaps deceptively so considering the lack of marked topographic relief in the area. The natural complexity is related not only to present climatic, geologic and soil conditions, but also to the historical biogeography of the region. See Figure 17. At the present time, man is a crucial environmental factor as he is over much of the earth. The effects of many of man's activities have often been to reduce natural ecological complexity. Man has superimposed a considerable diversity of activities upon the naturally complex environment.

The predominant factors responsible for the geographical pattern of change of terrestrial and freshwater biological diversity over the region are a climatic gradient of moisture and temperature and edaphic changes. Moisture decreases and temperature increases from northeast to southwest. The Texas coast can be divided into three climatic belts ranging from a humid region from the Louisiana border to Galveston, to a region ranging from wet sub-humid near Galveston to dry sub-humid near Corpus Christi, to a semi-arid section from Corpus Christi to the Rio Grande. Average annual temperatures range from 21°C at Sabine Pass to 24°C at Brownsville. Rainfall varies from 140 cm per year in the northern regions to 66 cm on the lower reaches of the coast.

Six different terrestrial ecoregions have been recognized for this area (Bailey, 1976). Three of these are humid forest zones including parts of the study area east of the Trinity River embayment. To the southwest of the mesic forest zones is a predominantly Oak(Quercus spp.) -Bluestem (Poaceae) parkland section which gradually changes to a predominantly Mesquite (Prosopis spp.)-Acacia (Acacia spp.) section in the region of Calhoun County, Texas. Desert communities are present in eastern Starr County, Texas. Within this same area Bailey (1976) recognized two major marine and estuarine systems, a West Indian Province extending north from the Mexican border to Calhoun County and a Louisianian Province extending from there to the Mississippi River Delta region and beyond. Within each of these major ecological regions there are many different biological communities. Some of this variety results from the terrestrial-coastal interface.

Along the Louisiana coast there is a marsh zone of variable width which includes four general types: saline marsh, brackish marsh, intermediate marsh, and freshwater marsh. This area encompasses some 7,289,588 acres of which 3,910,664 acres is marsh vegetation and 3,378,924 is surface water (Louisiana Wildlife and Fisheries Commission, 1971). The physiography of the Louisiana coast varies from an irregular broken shoreline at the Mississippi state line with salt to brackish marshes, to the Mississippi Delta containing salt, brackish, and freshwater marshes, and finally to the estuarine system of the Chenier Plain in the western section containing extensive salt and freshwater marshes and a shoreline that is regular and unbroken. Average air temperature for the Louisiana coast range from 16.5 to 19.8°C in winter and 23.1 to 31.9°C in summer (Sanders, 1959). The average annual rainfall for the area is 152 cm. Both temperature and precipitation are more uniform for the Louisiana coast than for that of Texas.

The barrier islands along the Texas coast enhance the biological diversity of the region. This coast is characterized by a continuous series of bays, estuaries, and lagoons from Sabine Lake to Laguna Madre. The Texas Coastal Plain is drained by ten major river systems which enter the bays or discharge directly into the Gulf. The bays are normally headed by alluvial plains and deltas which usually support marshes. The seaward sides of bays are protected by barrier islands. The shores of many bays and both sides of barrier islands consist of many miles of fine sand beaches, tidal flats or marshy areas. The Texas coastal system contains 398,080 acres of marsh and 1,344,000 acres of bays and estuaries.

The predominant human influence in the Gulf Coast region is commercial including agriculture. Seventy percent or more of the land is under commercial use of one sort or another. Because of the predominantly monoculture management practices of much of modern agriculture, many of the terrestrial biological communities of the region have been greatly simplified and therefore have probably become less ecologically stable than the natural communities which once were predominant. There are several major residential-industrial centers in the region. The estuarine systems are some of the most productive in the world, and support large fisheries industries, provide a valuable recreational resource, and also include habitats for a number of species threatened with extinction. Some of the major ecological conflicts in the region arise from the values of the above wetland-related activities and those of other, sometimes incompatible uses, such as those of heavy industry. The resolution of such conflicts in the future will tax the abilities of all of society (Blevins and Novak, 1975).

RATIONALE FOR EXPLOITATION OF GEOPRESSURED ENERGY RESOURCES

The impetus to utilize geopressured geothermal energy resources has arisen from increasing demands by modern high technological industrial societies for energy sources beyond those presently available. Some of the latter are rapidly being depleted. In considering the potential of geopressured-geothermal energy, it is appropriate to compare it with other present and future sources. The discussion to follow is a comparison of ten major energy resources on a global basis. Factors affecting the availability of the energy resources and ecological problems associated with their exploitation are considered. The sources are discussed in the order of their present levels of exploitation, beginning with solar and concluding with nuclear fusion which is still a theoretical source. The discussions of non-geothermal resources are based largely on information from Lovins (1976) and Southwick (1976).

Comparison of availability of geothermal and other energy resources

Factors which affect the availability of ten major energy resources are compared in Table 3. Included are the abundance of the resources, the status of technology for exploitation, and geographic localization.

Table 3. Factors affecting availability of energy resources.*

ENERGY RESOURCES	Availability of Source				Availability of Technology		Localization of Source
	Quantity available now	Duration of future availability	Is resource renewable?	Quantity possibly available in future	Quantity available now†	Quantity possibly available in future	
1. Solar							
a. biological							
(1) food	large	permanent	yes	large	much	more but different	localized in regard to latitude, weather patterns, and time cycles
(2) wood							
(a) construction	large	permanent	yes	large	much	more but different	localized in regard to latitude, weather patterns, and time cycles
(b) shade trees	large	permanent	yes	large	much	same	localized in regard to latitude, weather patterns, and time cycles
(c) fuel	large	permanent	yes	large	much	same	localized in regard to latitude, weather patterns, and time cycles
b. direct							
(1) thermal	large	permanent	yes	large	much	more	localized in regard to latitude, weather patterns, and time cycles
(2) hydrothermal	large	permanent	yes	large	much	more	localized in regard to latitude, weather patterns, and time cycles
(3) electrical generation							
(a) wind	large	permanent	yes	large	moderate	more	localized in regard to latitude, weather patterns, and time cycles
(b) waves	large	permanent	yes	large	small	more	localized in regard to latitude, weather patterns, and time cycles
(c) silicon cells	large	permanent	yes	large	small	?	localized in regard to latitude, weather patterns, and time cycles
(d) cadmium cells	large	permanent	yes	large	small	?	localized in regard to latitude, weather patterns, and time cycles
2. Oil and natural gas	large	30 years	no	small	much	same	geologically localized
3. Coal	large	500 years	no	small	much	more but different	geologically localized
4. Hydroelectric	moderate	permanent	yes	moderate	much	same	hydrologically localized
5. Nuclear fission	moderate	50 years	no	small	partial	?	localized
6. Cogeneration	large	limited except for solar, hydroelectric, and tidal	yes, for solar, hydroelectric, and tidal only	smaller	moderate	more	localized in regard to primary sources
7. Geothermal							
a. steam	small	30 years	?—probably not	small	partial	?	geologically very localized
b. normal pressure hydrothermal	moderate	?	?	?	partial	?	geologically very localized
c. geopressured hydrothermal	very small	30 years	no	small?	partial	?	geologically very localized
8. Tidal	large	permanent	yes	large	small	?	coastlines
9. Oil shale	moderate	100-200 years	no	small	partial	?	geologically localized
10. Nuclear fusion	possibly very large	possibly permanent	no	possibly very large	none	?	near water

† much = *technology available now and hardware is produced on a large scale*
moderate = *technology available now and hardware is produced on a moderate scale*
small = *technology available now and hardware is produced on a small scale*
partial = *only part of needed technology is available*

*Based largely on Lovins (1976) and Southwick (1976).

When biological utilization is included, solar energy is the largest resource presently being utilized as well as probably the largest potentially available in the future. Problems associated with exploitation of the resource include variations in intensity of radiation with latitude, weather patterns, and day length. These can be somewhat alleviated by various "soft technology" storage methods. Methods of utilization of solar energy include biological (agriculture and use of natural biological communities), thermal, hydrothermal, wind or wave electrical generation and photoelectric conversion. Technology is rapidly developing for increased utilization of this source. Future availabilty is large because of the potentially permanent nature of the resource.

Oil and gas reserves have been major energy resources of the twentieth century. Technologies for utilizing them are advanced, but at projected consumption rates, reserves may last for only another thirty years. The resources are geologically localized and must often be transported great distances before being converted to other energy forms for utilization. The fact that the resources are non-renewable has led to the search for other energy sources.

Projected reserves of coal may last 500 years assuming maximal exploitation (Southwick, 1976). The resource is finite and non-renewable. Technology involved with the recovery of coal includes deep mining and strip mining. Fluidized bed combustion offers promise as a conversion process. The resource is highly localized and therefore involves considerable transport for utilization.

Hydroelectric energy has been an important electric power generating method, but localization of the resource has limited its utilization. Technology is extensive and the resource might be permanent and renewable if reservoir filling by siltation could be avoided. Lovins (1976) indicates that current levels of hydroelectric production would be sufficient to meet many of the essential needs of modern industrial societies if non-essential applications of electric energy, such as heating and cooling, were eliminated by use of "soft technologies."

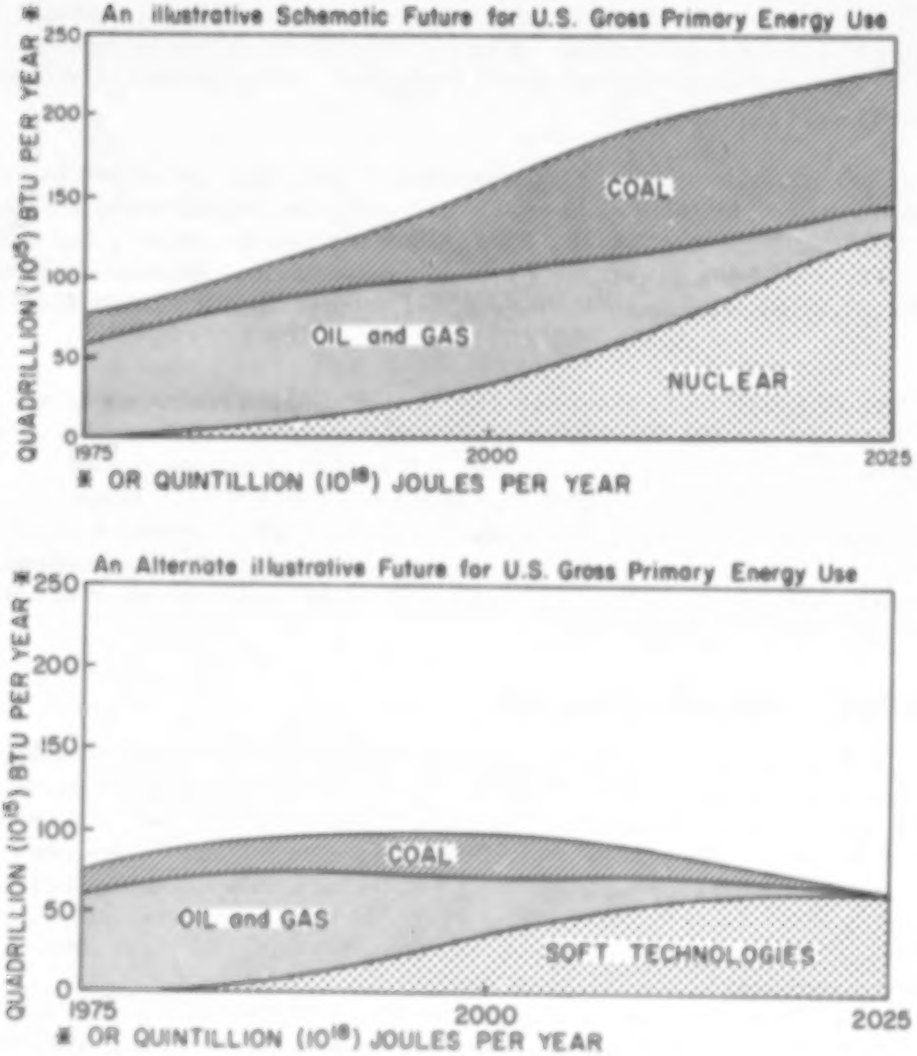
Another moderate source of electrical energy is nuclear fission, but again, these fuels are a finite resource and are non-renewable. Uranium ores are highly localized and are predicted to last for approximately 50 years at projected consumption levels and exploitation plans (Southwick, 1976). The quantities of these fuels requiring extensive transport are much smaller than those of fossil fuel resources. Electric conversion technology is extensively developed now, but no solutions are yet proved for the technological or sociopolitical problems of long-term storage of radioactive wastes.

A long overlooked energy resource is cogeneration of electricity by utilization of heat produced as a byproduct of other industrial energy facilities. Although its potential is now high, such will probably be less in the future when fossil and nuclear fuels are exhausted. However, it could be permanently utilized in combination with solar, hydroelectric, and tidal energy systems. It is localized with regard to the energy exploitation system with which it is combined.

Geothermal energy resources include geothermal steam, normal pressured hydrothermal and geopressured-hydrothermal deposits. Of the three, normal pressured sources appear to be the most promising substantial contributor to energy budgets. Geothermal steam deposits are very few and geopressured-hydrothermal deposits having geological characteristics suitable for exploitation may be limited (See Phase I). Steam and geopressured-geothermal resources are thought to be nonrenewable; the predicted life of such fields is estimated at 20-30 years. Technology for exploitation of geothermal resources is partially developed; that for exploration, production and waste disposal is similar to that utilized by the petroleum industry. Geothermal resources are highly localized.

In terms of available technology, distribution and abundance, and the general nature of the resource, it appears that geothermal energy may function primarily as a supplemental energy source during periods of long term energy technological development (e.g. solar systems). The resource might not be a feasible energy source if new technology were necessary, but if petroleum exploration and waste injection procedures can be utilized and scaling and waste containment problems in electric conversion facilities can be solved, the potential is enhanced. Geopressured-geothermal resources will require deep drilling (See Phase I) and cost factors may deter development; but increased prices of other fuel sources could result in greater economic impetus to develop these geothermal resources.

Because geopressured resources are probably non-renewable, their exploitation is an example of reliance on "energy capital" rather than "energy income" as recently elaborated by Lovins (1976). Their role in overall energy budgets may be compared to that of oil and gas, though on a much smaller scale. See Figures 15a and 15b. Lovins (1976) predicted that energy consumption by the year 2025 could be no greater than that of today with no substantial degradation in many of the features which modern society considers hallmarks of its high quality of life (Figure 15b). This energy strategy would involve conservation efforts as well as implementation of what Lovins terms "soft technologies." It is in marked contrast to a projected fourfold increase in energy production of many predictions of need for implementation of expensive high technologies during the same period (Figure 15a).



Figures 15a and 15b. Alternative illustrative futures for U.S. gross primary energy use. From Lovins (1976).

Tidal generation of electricity may have promise if technology can be developed for its exploitation. It is especially attractive because of the permanent and renewable nature of the resource. It is limited to coastlines with appropriate tidal ranges.

Oil shale deposits are a non-renewable resource predicted to be available for the next 100 to 200 years. Most of the deposits are localized in Colorado and Utah (Southwick, 1976). Technology for mining and extraction of petroleum from oil shale is currently available. Utilization of the resource after processing would be similar to that used for other fossil fuels.

The utilization of heavy water in nuclear fusion reactions is a theoretical energy resource. The practicability of this will depend in part upon future technological developments. If such technology can be achieved, the extent of the exploitable resource may be very large. Requirements of rare metals for proposed technological systems might seriously limit its potential scale (Andersen, personal communication). Localization may result from necessities of siting facilities near sources of water for both fuel and cooling.

Ecological problems and mitigations

Ecological problems associated with exploitation of major energy resources are summarized in Table 4. Geothermal resource exploitation shares many of the ecological problems of other energy systems and has some unique ones. Problems shared with petroleum-based resources include spills of fluids, construction of roads, possible dredging and filling in wetland areas, disposal of drilling fluids and rock cuttings, noise, power transmission lines, pipelines of various descriptions, and land areas affected by production and injection wells. Total land surface area compared to other power generating methods, principally because the number of fields with geological characteristics suitable for exploitation may be very limited (see Phase I). It may be necessary to construct water towers for cooling purposes, thus including aerosol drift of treatment compounds (biocides) and/or geothermal fluids to surrounding areas. Depending on the exploitation scenario, structures may be located offshore in the Gulf, in bays and estuaries, and/or on land. Solid wastes, organic pollutants, heat and noise common to other industrial complexes will undoubtedly occur.

Unique problems associated with exploitation of geopressured-geothermal resources involve the handling of huge quantities (as much as 50,820 m^3/day (310,000 bbl/day)) of geothermal fluids at very high temperatures (150°C). Land subsidence and surface faulting may result from withdrawal of these fluids. Fluids may be very saline and possess ionic proportions

Table 4. Factors contributing to ecological problems of exploitation of energy resources.*

ENERGY RESOURCES	Methods of Transport of Resources						Ecological Problems															
							Land Effects		Pollutants										Requirements of other Scarce Resources			
	pipelines	trucks	rail	ships	microwave	electrical transmission lines	amount of land required	subsidence	solid waste	organics	combustion products	brine	acids	other toxic substances	radioactive isotopes	heat	noise	aesthetics	fresh water	land	capital for implementation	management time after use
1. Solar																						
a. biological																						
(1) food	−	+	(+)	(+)	−	−	◯large	+	(+)	(+)	+	−	−	−	−	+	(+)	+	⊕	⊕	+	−
(2) wood																						
(a) construction	−	+	+	+	−	−	◯large	−	(+)	+	+	−	−	−	−	+	(+)	−	⊕	⊕	−	−
(b) shade trees	−	+	−	−	−	−	large	−	−	−	+	−	−	−	−	−	−	−	⊕	+	+	−
(c) fuel	−	+	+	+	−	+	large	−	⊕	+	⊕	−	−	−	−	⊕	+	+	⊕	⊕	+	−
b. direct																						
(1) thermal	−	−	−	−	−	−	small	−	−	−	−	−	−	−	−	−	−	−	−	−	⊕	−
(2) hydrothermal	+	−	−	−	−	(−)	(small)	−	−	−	−	−	−	−	−	−	−	−	+	−	⊕	−
(3) electrical generation																						
(a) wind	−	−	−	−	−	+	moderate	−	−	−	−	−	−	−	−	−	⊕	+	−	−	⊕	−
(b) waves	−	−	−	−	−	+	small	−	−	−	−	−	−	−	−	−	−	+	−	−	⊕	−
(c) silicon cells	−	−	−	−	(+)	(+)	(small)	−	−	−	(−)	−	−	−	−	(+)	−	+		(−)	⊕	−
(d) cadmium cells	−	−	−	−	(+)	(+)	(small)	−	−	−	(−)	−	−	⊕	−	(+)	−	+	−	(−)	⊕	−
2. Oil and natural gas	+	+	+	+	−	+	(large)	+	+	⊕	⊕	⊕	−	+	−	⊕	+	⊕	⊕	⊕	+	−
3. Coal	⊕	+	+	+	−	+	(large)	−	⊕	⊕	⊕	−	⊕	⊕	(−)	⊕	+	⊕	⊕	⊕	⊕	+
4. Hydroelectric	+	−	−	−	−	+	moderate	−	−	−	−	−	−	−	−	+	+	⊕	⊕	⊕	+	+
5. Nuclear fission	+	+	+	+	−	+	small	−	+	−	+	−	−	−	⊕	⊕	−	−	⊕	−	⊕	⊕
6. Cogeneration	−	−	−	−	−	+	small	−	+	−	−	−	−	−	−	+	−	−	+	−	+	−
7. Geothermal																						
a. steam	+	−	−	−	−	+	small	−	+	+	+	+	+	⊕	(−)	+	+	+	−	+	+	?
b. normal pressure hydrothermal	+	−	−	−	−	+	moderate	+	+	+	+	⊕	−	⊕	−	+	+	+	(+)	+	+	?
c. geopressured hydrothermal	+	−	−	−	−	+	moderate	⊕	+	+	+	⊕	−	⊕	−	+	+	+	(+)	+	+	?
8. Tidal	−	−	−	−	−	+	small	−	−	−	−	−	−	−	−	−	−	?	−	−	⊕	−
9. Oil shale	+	+	+	+	−	+	large	?	⊕	+	+	−	?	?	?	⊕	+	⊕	⊕	⊕	+	(+)
10. Nuclear fusion	+	−	−	−	−	+	small	−	?	−	−	−	−	−	⊕	⊕	?	?	⊕	-?-	⊕	⊕

− *indicates there is not a problem for a particular resource*
+ *indicates a potential problem for a particular resource*
◯ *indicates a particularly serious problem*
( ) *indicates that there may or may not be a problem*

*Based partially on Southwick (1976).

different from that of seawater. In addition, the brines may contain toxic substances such as ammonia, boron, hydrogen sulfide, beryllium, cadmium, or lead. The presence of the latter two elements in one geopressured water sample may have resulted from contamination (Gustavson, personal communication). (See section on disposal of brines.) The large quantities of fluids withdrawn will require that extensive surface holding ponds be constructed capable of temporarily storing fluids in the event of: 1) blowouts during drilling or well maintenance, 2) possible pipeline breaks or leaks, and 3) shut-down of generating facilities during which time brine flow might continue. The silica and salts present in geothermal fluids and their corrosion products will require regular use of some sort of scouring technique to keep pipes open for normal flow, which may involve additional disposal problems.

If injection of geothermal effluents is feasible, and uncontrolled spills can be prevented, then ecological impacts of geopressured-geothermal exploitation may be minimized compared to other currently effective electrical energy conversion systems, with the possible exceptions of hydroelectric and cogeneration. Although some other systems may be characterized by even fewer negative environmental impacts (e.g. solar and tidal), the technology for such systems is not fully developed. It appears that geopressured-geothermal energy production may be a small and relatively short-term energy source resulting in environmental problems much like those of fossil fuel systems.

ECOLOGICAL RESOURCES OF THE GULF COAST

The following is a summary of ecological resources of coastal Louisiana and Texas. These resources include both human systems and the natural ones on which they depend. Both could be affected by exploitation of geopressured-geothermal energy resources.

DIRECT HUMAN USE OF THE COASTAL ZONE

Current land use

The predominant use of land in this coastal region is commercial related to agriculture, petrochemicals, tourism, ports and other transportation, and manufacturing. Agriculture and related industries account for 70 to almost 100 percent of the principal land commitment. The types of agriculture vary, reflecting partially the natural ecological resources in the region. Grazing and crop lands are extensive. Forestry is important inland from the upper Texas coast and in southern Louisiana. Oil and gas fields are common throughout this zone, and there are also major refining and distribution centers near Corpus Christi, Houston-Galveston, Beaumont-Port Arthur, and Lake Charles. Corpus Christi, Houston-Galveston, and New Orleans are important ports. Houston is a major distribution point for air traffic. Tourism is extensive, particularly on the beaches of the barrier islands of the Texas coast. There are transportation systems including highways, roads, and dredged canals in addition to the port related activities described above. The Houston-Galveston area in particular has become an important manufacturing center for a diversity of products besides petrochemicals including foods, sulfur, wood products, and other construction materials. In addition to the cities mentioned above, there are several other urban areas including Brownsville, Harlingen, and Kingsville which are agricultural centers of the lower coast; Victoria in the central coast; Baytown and Orange in the upper Texas coast; and Lafayette and Houma in southern Louisiana. For detailed land use maps of this region and tabulations of acreages under different uses, see Fisher *et al.*, 1972, 1973; Gagliano *et al.*, 1972; General Land Office of Texas, 1975; McGowen *et al*, 1976 a, b; and Brown *et al*, 1976 and in press. Generalized land use maps of Louisiana and Texas are in Phase I of this report (Figures 7a, b).

Parks, biological reserves and other areas of particular ecological interest are located within this coastal region. These include Bentson-Rio Grande Valley State Park (SP), Santa Anna National Wildlife Refuge (NWR), Las Palomas State Wildlife Management Area (SWMA), Del Mar Brazos Island SP, Laguna Atascosa NWR, Padre Island National Seashore, Baffin Bay Rural Natural Area (RNA), Oso Creek Urban Natural Area (UNA), Mustang Island SP, Mustang Island Shores State Recreation Area (SRA), Lake Corpus Christi SRA, Live Oak Peninsula UNA, Goose Island SRA, Aransas NWR, Matagorda Island RNA, San Bernard NWR, San Bernard River Scenic Waterway (SW), Bryan Beach SRA, Brazoria NWR, Upper Buffalo Bayou UNA, Post Oak Area near Hempstead, Lone Star Hiking Trail (USFWS), W. Goodrich-Jones State Forest (SF), Sheldon SWMA, Lipantitlan State Historical Site (SHS), Bird Flats UNA, Armand Bayou UNA, Prairie Chicken Habitat UNA, Galveston Island SP, Tanner Bayou RNA, Trinity River Recreational Waterway (RW), Anahuac NWR, Black Rail Salt Marsh RNA, Smith's Woods RNA, J. B. Murphree SWMA, Sea Rim SP, Texas Point Salt Marsh RNA, Sabine River SW, Lower Sabine Cypress Swamp UNA, Orange County Park, Parts of Big Thicket National Preserve, Neches River SW, Big Sandy and Village Creek Wild Waterway (WW), Big Sandy Creek RNA, Pine Island Bayou RNA and Pine Island Bayou SW (General Land Office of Texas, 1975, Plates 11Ai and 11Bi). Those plates show the locations and sizes of these areas. Major areas in Louisiana are the Sabine NWR, Rockefeller MWR, Sam Houston SP and Lacassine NWR.

Current aquatic usage

The coastal waters of the Texas-Louisiana area form an important natural resource base for economic activities. There are three economic sectors that depend directly upon coastal waters: waterborne transportation, commercial fisheries, and recreation and tourism (General Land Office of Texas, 1976). The availability of water transportation is an important reason for siting of petroleum refineries, metalurgical complexes, and chemical industries in the coastal regions of the Gulf. The maritime shipping lanes are valuable to agricultural activities because they open world markets to grain and cotton farmers.

Of the ten deep water ports in Texas, the ports of Houston and Corpus Christi and the combined ports of the Sabine-Neches waterway are among the largest in the world. Three quarters of all goods shipped to other states from Texas travel by water. In terms of generated capital, shipping is responsible for approximately $448 million per year in the state. The indirect effect throughout the state and the nation amounts to about $1.6 billion per year. The Gulf Intracoastal Waterway which extends 426 miles along the Texas coast, carried more than 66 million tons of cargo in 1974 (General Land Office of Texas, 1976).

The major ports in Louisiana are New Orleans, Baton Rouge, and Lake Charles. The combined length of all channels and canals in Louisiana was estimated to be 7,317 kilometers (4,573 miles) in 1970 (Barrett, 1970). Many of these are devoted to transportation of petroleum and other industrial products.

The commercial fishing industry on the Texas coast amounted to almost 40.14 million kilograms (88.5 million pounds) of finfish and shellfish in 1975 with a market value of $93 million (U.S. Department of Commerce, 1976). The indirect effects of this production throughout the state and the nation total nearly $350 million per year. The Louisiana catch of 510 million kilograms (1,125 million pounds) of commercial fish and shellfish accounted for 66% of the Gulf of Mexico total for 1975 (U.S. Department of Commerce, 1976). Estuarine dependent species-Menhaden (Brevoortia patronus), shrimp, oysters, crabs, and certain industrial bottomfish made up 98% of Louisiana's total catch. Shrimp are the most valuable fishery resource. During 1976 there were 220 commercial fishery wholesale and processing firms in Louisiana with a value of products of over $68 million.

Menhaden (B. patronus) support the largest commercial fishery in North America (Reintjies and Pacheco, 1966). The largest catches come from the Gulf of Mexico, and these are concentrated in the waters of Louisiana (Gunter and Christmas, 1960). During 1959-1963, 38,000 to 48,000 tons of industrial bottom fish were harvested from the northern Gulf of Mexico (Roithmayr, 1965). It is obvious that the waters of the Texas-Louisiana coasts abound in finfish and shellfish which support an important commercial fishing industry.

The large coastal tourist industry depends not only on the diversity of fish and wildlife, but on scenic views, open beaches, wetlands, and clean air and water. It has been estimated that some 750,000 Texans currently engage in recreational fishing in Texas coastal waters. These sportsmen catch over 18 million kilograms (40 million pounds) of Speckled Trout (Cynoscion nebulosus), Redfish (Sciaenops ocellata), Drum (Pogonias cromis), shrimp (Penaeus spp.) estimated to produce "net economic benefits" to Texas of over $19 million annually. Gunter (1967) has estimated the annual sport fishing catch of estuarine fishes of the Gulf Coast to be at least 45 million kilograms ($100 million pounds) and perhaps greater. In addition to the sports fishery, the Texas-Louisiana coastal region is located in the heart of the Central and Mississippi Flyways for a large variety of migratory birds. Fish, waterfowl and other game animals bring thousands of hunters and sports fishermen to the Gulf Coast every year. Recreation and tourism are estimated to generate $585 million annually in Texas alone.

The rivers, lagoons, bayous, estuaries and bays of the coastal zone are used for surfing, sailing, swimming, sun-bathing, scuba diving, water skiing, sport fishing and motor boating. Marine recreation and tourism had an estimated 1970 market value of $14.5 billion and by far exceeded fishery and mariculture ($3.1 billion), oil and gas ($5.0 billion), and the chemical and mineral industries (0.4 billion) (Lemmon, 1971). Economists anticipate an increase of at least $100 million a year in national expenditures for marine recreation over the next two decades (Committee on Oceanography, 1964).

In addition to the industrial, commercial and recreational uses of the coastal waters of the Texas-Louisiana region, these waters are important receptacles for large quantities of industrial and domestic wastes. The Orleans-Jefferson Parishes and the Houston-Galveston area have the highest concentrations of wastes emptying into the coastal estuaries. The average discharge of domestic wastes along the Louisiana coast is approximately 528,000,000 liters (125,000,000 gallons) per day, while the industrial wastes are in excess of 6,087,000,000 liters (1,440,000,000 gallons) per day.

NATURAL ECOLOGICAL SYSTEMS OF THE REGION

Marine ecological zonation

Major problems arise in attempts to describe the ecological and biogeographical zones of nearshore and estuarine environments, and it appears that it will be some time before a solution is reached. In Bailey's (1976) classification of marine provinces of the United States, the Gulf Coast area as previously defined is included in two provinces: The Louisianian and the West Indian. The Bailey system terminates at the ocean boundary. The combination of the Bailey system with the wetland classification of marine and estuarine realms (Ketchum, 1972; U.S. Fish and Wildlife Service, 1976) has led to a description of these two provinces for the areas of concern in this study.

The Louisianian Province extends along the northern coast of the Gulf of Mexico and includes Louisiana and the northern coast of Texas to Port Aransas. It contains extensive marshes and well-developed barrier islands. Waters are turbid and productive. The biota is temperate with seasonal tropical elements. The Gulf waters and weather patterns are the primary physical influences, and water temperatures in winter reach a minimum of 10°C; summer temperatures are tropical. The tidal range is small.

The West Indian Province includes the coastal areas from Port Aransas to the Texas-Mexico border. The shorelands of most of this province including the Caribbean Islands and Mexico are low lying limestones with calcareous sands and marls. The shorelands of the Texas portion of this zone are principally low-lying silicious sands and muds. The biota is tropical. Reef corals and mangroves are common to much of this province, but these communities are rare or absent from the Texas portion. Minimum water temperatures are about 20°C and tidal ranges are small.

Many attempts have been made at classifying ecological systems by energy relationships, environments, and biotypes. Among the most notable for the Gulf Coast are those of the Bureau of Economic Geology (Fisher _et al._, 1972, 1973; McGowen _et al._, 1976a, b; Brown _et al._, 1976 and in press), Gagliano _et al._ (1972), Oppenheimer and Gordon (1972), Harcombe (1974), Odum et al. (1974), Blevins and Novak (1975) and General Land Office of Texas (1976, 1975). The following descriptions of aquatic systems are based on the literature with specific examples of the various systems within the Texas-Louisiana coastal zone. Examples of the characteristic biota for each zone are listed in Appendix A. Figure 16 illustrates a hypothetical bay system showing distributional relationships of the various resource areas. The above references contain maps of these areas and tabulations of acreages. See particularly the Bureau of Economic Geology atlases and General Land Office maps.

Near shore gulf

Salinity usually remains constant in the 30,000-35,000 ppm range. Within any season, temperatures remain relatively constant, but vary throughout the year from 12-32°C. Nutrient levels tend to be high, but lower than in bay areas. Water circulation is typified by slow-moving longshore currents. Depth ranges from 5 meters to several hundred meters at the continental shelf. The bottom has little relief and the substrate is chiefly mud and sand. Food chains tend to be long and are based

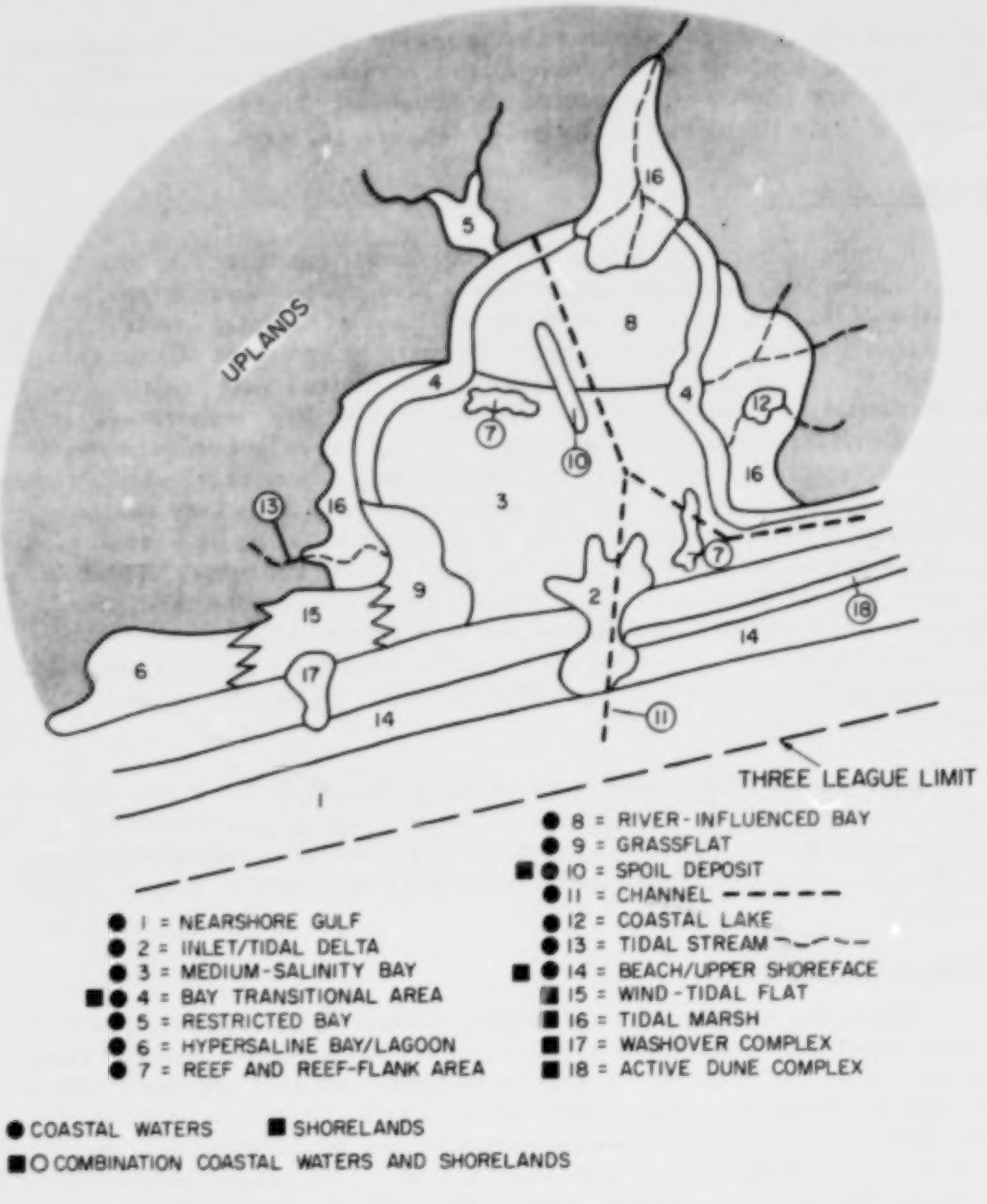

UPLANDS
16
5
8
4
7
10
4
12
16
13
16
3
9
2
7
18
15
6
17
14
14
11
1
THREE LEAGUE LIMIT
● 1 = NEARSHORE GULF
● 2 = INLET/TIDAL DELTA
● 3 = MEDIUM-SALINITY BAY
■● 4 = BAY TRANSITIONAL AREA
● 5 = RESTRICTED BAY
● 6 = HYPERSALINE BAY/LAGOON
● 7 = REEF AND REEF-FLANK AREA
● 8 = RIVER-INFLUENCED BAY
● 9 = GRASSFLAT
■● 10 = SPOIL DEPOSIT
● 11 = CHANNEL
● 12 = COASTAL LAKE
● 13 = TIDAL STREAM
■● 14 = BEACH/UPPER SHOREFACE
■ 15 = WIND-TIDAL FLAT
■ 16 = TIDAL MARSH
■ 17 = WASHOVER COMPLEX
■ 18 = ACTIVE DUNE COMPLEX
● COASTAL WATERS
■ SHORELANDS
■○ COMBINATION COASTAL WATERS AND SHORELANDS

Figure 16. Composite resource areas of Gulf Coastal waters and shorelands. From General Land Office of Texas (1976).

on phytoplankton with zooplankton as the major consumers. Many species of protozoans, coelenterates, ctenophores, crustaceans and members of other phyla are locally and sporadically abundant. Many species spend portions of their life cycle in this area. Figure 16, area 1.

Inlet/tidal delta

Salinity ranges from near fresh to marine conditions 1,000-35,000 ppm, although it is normally intermediate between bay and marine levels. Rainfall and flooding result in rapid fluctuations of salinity levels. Turbidity is usually high, and considerable amounts of sediment and organic material are transported in these areas. Temperatures vary widely (10-35°C) and are under the influence of the adjacent shallow bay temperature regimes. Environmental variables depend to a great extent on the tidal cycle and wind driven currents. Very strong currents are characteristic and are influenced by tides, storms and heavy rainfall. At times they exhibit bidirectional flow. Inlets are areas of continual shoaling or scouring, usually with a deep channel and nearby shallow channel margins. Tidal deltas are found on both the bay and Gulf sides. Substrate may be mud, sand, shell or a combination depending on the sediment source and water velocity. The biota are usually either planktonic, strong swimmers, sessile, burrowing benthic species or migrating forms at some stage of their life cycle.

Examples of inlet/tidal delta areas for the Gulf Coast are Southwest Pass to Vermillion Bay, and Calcasieu Pass in Louisiana; Sabine Pass, Bolivar Pass, San Luis Pass, Freeport Harbor Entrance, Matagorda Pass, Pass Cavallo, Aransas Pass, and Brazos Santiago Pass in Texas. Figure 16, area 2.

Medium-salinity bay

These bay systems are influenced at their upper reaches primarily by river input and at the lower reaches by marine waters. Salinity range is generally on the order of 10,000-35,000 ppm and may approach 100 ppm with high freshwater inputs. Temperature varies from 1 to 35°C seasonally. Nutrient levels vary considerably and may be influenced by waste discharge. Turbidity varies with wave action. Low oxygen levels often occur during the summer months, especially at night. Although circulation tends not to be restricted, circulation patterns are complex and are under the influence of tides, freshwater inflows, discharges, evaporation, precipitation, morphology of the basin, coastal orientation, and wind. Typical depths range from two to five meters with low relief bottoms mostly of mottled mud. Bay orientation tends to be perpendicular to the coast line. Food chains are phytoplankton based, and zooplankton are the primary consumers. There may be as many as five levels of organisms in the food chain. Small filter-feeding invertebrates, benthick filter feeders and suspension feeders, scavengers, and large predators are typical. Species diversity is high.

Calcasieu Lake in Louisiana and Sabine Lake and Galveston Bay in Texas contain areas that are typical of the medium-salinity bay. Figure 16, area 3.

Bay transitional area

A bay transitional area is a transition zone usually occupying the edge of coastal waters or acting as a buffer between other estuarine areas. Therefore it has characteristics which result from combinations of zones on either side, and these characters must be determined on an area-specific basis. Temperature, salinity and turbidity are all highly variable. Water characteristics are influenced by runoff and local shoreline conditions. Water movement and circulation are also highly variable and may be influenced by wind related wave action, channel currents, tidal flow, and freshwater input. In some areas water movement may be limited and almost exclusively subject to winds and tides. These areas tend to be shallow, usually less than one meter deep. Substrate is sand to mud and varies with water movement. A transitional area may have sparse stands of marsh plants or sea grasses. They may contain seasonal concentrations of juvenile fish, shrimp, and crabs. Other biota tend to be characteristic of the adjacent areas: medium-salinity bays, wind-tidal flats, restricted bays, hypersaline bays, grass flats, tidal marshes, and river influenced bays.

Examples of transitional areas may be found in most of the bay systems along the Texas-Louisiana coastal zone. Figure 16, area 4.

Restricted bay

Salinity and other chemical characteristics are related to the adjacent bay type. Salinity normally ranges from 10,000 to 35,000 ppm. Poor circulation is not uncommon and may result in reverse salinity gradients. Low oxygen concentrations occur in deep areas and reducing environments are common near the sediment-water interface. There is little tidal influence; wind and storms are the only major mixing agents. Depths usually range from one to three meters, and inlets and outlets are restricted. These bays may be headed by small creeks and are variable in shape. Substrates are highly organic muds. Although there tend to be large numbers of individuals present, species diversity is generally very low.

These bay systems are common in Texas and are typified by St. Charles Bay, Oso Bay and Carancahua Bay. Few if any examples of this type of system can be found in Louisiana because of the "marshy" nature of the coast which allows for little restriction of the bays in that area. Figure 16, area 5.

Hypersaline bay/ lagoon

Salinity ranges from 35,000 to 60,000 ppm and may reach 85,000 ppm. Selective precipitation of inorganic salts may occur at the higher salinities and ionic ratios may be different from seawater. Turbidity varies, and high concentrations of dissolved organic matter are common. Temperatures vary to extremes (0 - 44°C) especially in the very shallow areas. In areas of poor circulation and mixing, in conjunction with high temperatures and salinity, anaerobic conditions may result. The pH may also be quite different from that of seawater. The major portion of the mixing that occurs is a result of wind action or channel flow through the lagoon. Circulation problems may result from local spoil placement.

These systems are usually long and narrow, paralleling the coastline behind a barrier island. Depths are generally less than two meters in the lagoon system and up to four meters in the hypersaline system. Substrates tend to be very complex and may be locally laminated. Occasionally bay margin sands are calcite-coated, and oolites may be present. Deep bays are usually characterized by mud sediments, while shallow lagoons have more sand. Serpulid reefs and beach rock are found in these systems.

Species diversity is often very low, but some species may be very abundant. Those that are present are highly adapted forms able to cope with high salinities, temperature extremes, variations in oxygen concentration, and unusual ion compositions. Food chains consist of producers, small herbivorous fish and invertebrates, and a few large carnivores. Laguna Madre and associated bays in southern Texas are prime examples of these hypersaline systems. They do not occur in Louisiana because of the high freshwater inflow characteristic of the region. Figure 16, area 6.

Reef and reef-flank area

Oyster reef areas are generally found in medium-salinity bays, river-influenced bays, and to a lesser extent restricted bays. Temperature (1 - 35°C) and salinity (100 - 35,000 ppm) vary seasonally. Oysters usually do not thrive with prolonged exposures at the limits of these ranges. Turbidity may vary for a short time, but extended periods of high turbidity are unusual. Waters near reefs are usually high in concentrations of live or dead particulate matter which the oysters utilize. There is generally a significant unidirectional current, and the reefs alter circulation patterns as they grow.

Water depths usually are in the 0 to 3 meter range. Reefs are normally long and narrow and perpendicular to the major direction of water flow. Substrate of a reef consists of shell debris, dead reef material, or mixtures of muds, sands, and other hard materials upon which spat can set.

The oyster reef is a diverse ecological system. Crassostrea virginica is the characteristic species, but in higher salinity areas Ostrea equestris may be abundant. The ichthyofauna is usually similar to that found in medium-salinity, river-influenced, and restricted bays. Many species feed on the reefs or utilize them as a habitat and attract higher predators from adjacent areas. The other type of reef community found on the lower reaches of the Texas coast is the large, relict serpulid reef which is characterized by polychaetes, amphipods, and barnacles. Oyster reefs are found throughout the bay systems of the Texas-Louisiana coast. Figure 16, area 7.

River-influenced bay

Salinities in the river-influenced system range from 100 to 10,000 ppm and vary seasonally. Both temperature and salinity are under direct and continual influence of river inflow, especially storm runoff. Turbidity is normally high. Concentrations of calcium and sulfate are high, while those of sodium and chloride are lower than seawater. Dissolved and particulate materials are often high in concentration. Nutrients and trace elements may be abundant except during peak freshwater influxes. Toxic and pathogenic materials also occur. Salinity gradients may be significant, and salinity increases toward the Gulf.

The shape of the bay may range from long and narrow to round or nearly circular with a river or creek entering at its upper reaches. Depths are generally one to two meters. The bay receives large amounts of sediments, and bottom sediments usually consist of laminated silts, muds, and sands, all of which are organically rich. Species diversity is generally low because of salinity stress, and phytoplankton and grass may be limited by turbidity.

Many of the bay systems of Louisiana are representative of this system because of the discharge from the Mississippi and Atchafalaya Rivers. Mission Bay at the upper reaches of Copano Bay in Texas is also typical. Figure 16, area 8.

Grassflats-hypersaline

These grassflats usually occur in hypersaline lagoons and share their water characteristics. Salinity is rarely higher than 60,000 ppm and turbidity tends to be reduced by the short fetches normally associated with these areas and wave disruption by grass blades. Wind action is responsible for the majority of currents which are low to moderate. Typical depth is 30 to 60 cm with a smooth bottom and a substrate composed of fine-grained shelly sand and muddy shelly sand with a high organic content. The substrate is very stable because of rooted vegetation.

The distribution of seagrasses in these areas is directly related to salinity and is therefore variable on a seasonal basis. The grasses tend to die in the winter and the dead plant material is exported to other areas. Species diversity is high compared to hypersaline bays and lagoons, but lower than many other estuarine systems. Many species feed directly on the live seagrass or on dead organic material. There are several secondary consumers. Large portions of the Laguna Madre of Texas are typical of this system. Figure 16, area 9.

Grassflats-moderate salinity

Water characteristics of these areas follow the general patterns found in medium-salinity, restricted, or river-influenced systems to which they are adjacent. Turbidity is usually much less than in these other systems, and dissolved and particulate organic matter is found in high concentrations. Grassflats are typified by low wave action and low to moderate circulation patterns. Thalassia grassflats are associated with tidal passes and are more subject to tidal influence than many other grassflats.

Moderate-salinity grassflats normally occur along bay margins, especially in sheltered areas, where depths are 30 cm to 2 meters. They are also prevalent on shallow inlet tidal deltas. Bottom areas are smooth with mud to muddy sand sediments and considerable amounts of shell material. The substrate is very stable and contains large amounts of organic material. The ecological system is very diverse and contains most of the species found in the hypersaline grassflat and some additional ones. Species composition and abundance are under the influence of highly variable salinity, turbidity, and tidal regimes so typical of these areas. These grassflats are found on the margins of most of the bay systems of the Texas-Louisiana coast. Figure 16, area 9.

Spoil deposits

High turbidity levels are the most characteristic features of waters associated with spoil deposits. They are high at the time of deposit and may remain so for long periods depending upon the water currents and vegetative coverage. The deposits may contribute to high dissolved nutrient levels and/or low oxygen levels depending on the nature of the sediments. Concentrations of organic nutrients, volatile solids, oil and grease, sulfides, heavy metals, and adsorbed pesticides may increase in water because of spoil activities. Durations of high concentrations of these materials are highly variable and depend on local conditions.

The flow of water over and around spoil deposits is complex and dependent on the flow in nearby areas and the physical nature of the deposit area. These deposits can have far reaching influences on the circulation patterns of adjacent areas. There are no characteristic depth patterns, and they may range from emergent spoil islands to submerged mounds or a thin layer over the bay bottom.

There is no characteristic community structure in these areas because of the variable nature of the spoil and associated hydrological conditions. Burrowing invertebrates tend to be found shortly after spoil placement. After a period of several years these areas have a tendency to take on the characteristic flora and fauna of the inlet tidal delta, medium salinity bay, oyster reef, grassflat, wind-tidal flat, or tidal marsh, depending on the specific environmental parameters. Harwood *et al.* (1977) found that many older vegetated spoil islands were covered with plant communities typical of natural topographically "high" marsh. Figure 16, area 10.

Channels

Channels are either dredged for navigational purposes or water exchange, or they may be natural passes or inlets that have been stabilized to some extent. They often are very turbid because of high velocities of water passing through them. Dredged channels often carry significant amounts of industrial and municipal effluents, leaked or spilled materials from harbors, and runoff from cities and agricultural lands. These sources may contribute toxic or unusual chemicals to the system (General Land Office of Texas, 1976). Water movement is usually rapid and parallel to the channel. A channel may contain flows in different directions at various depths because of tides and salinity gradients. Channels are deep and may reach 15 m with an irregular bottom topography because of local bar formation and erosion.

Biota of the channels are similar to those of the inlet-tidal delta. Most organisms are burrowers, sessile,or strong swimmers and use the channel for migrational purposes, or are planktonic. The population determinant is the strong current. These systems are common in Texas and extremely plentiful in the wetlands of Louisiana. Figure 16, area 11.

Coastal lakes

Temperature and oxygen may be highly variable in a coastal lake. The general water characteristics are similar to that of the tidal marsh, but may exhibit much greater salinity variations because they are often discharge areas for small creeks and streams. Wind-tidal action and stream flow are the main influences on water movement, and circulation within the basin is dependent on channel connections with various parts of the associated marsh and bay systems. They may in some cases be the staging areas for all waterflow into and out of the marshes. They tend to be very shallow, ranging from one meter to a few centimeters deep, and may even dry up completely during drought periods. They are usually circular in shape and the substrate ranges from mud to sand with high organic content.

Consumers similar to those found in the tidal marsh are characteristic of coastal lakes, but the concentration of organisms is generally lower. Marsh plants are present, although they are usually sparse and the dominant producers are filamentous blue-green algae. These algae often form highly productive algal mats with their associated bacteria and microcrustaceans. These lakes are extremely abundant in the Louisiana coastal zone, less abundant on the upper Texas coast and nearly absent from the lower Texas coast. Figure 16, area 12.

Tidal stream reaches

Tidal stream reaches are the lower ends of streams which discharge into bay systems or the Gulf. Saltwater barriers, biological communities, and salinity regimes define the inland limits of the tidal stream reach. Water characteristics are variable and turbidity levels are typically higher than other areas of coastal waters. Salinity may vary from 500 ppm in high velocity streams to 35,000 ppm in low velocity waters. Reverse salinity gradients are not uncommon, and oxygen levels vary with depth. Dissolved and particulate organic matter and organic nutrients are often present in higher concentrations than found in other coastal waters. There may be high concentrations of sulfate and calcium, as well as toxins, municipal and industrial wastes, and pathogens. Climatic regime, basin substrate, and the extent of the drainage basin are responsible for the specific water characteristics.

High flow streams generally have a net freshwater movement toward the bay system, but tidal influence normally results in well mixed fresh and estuarine waters so that there is no well defined salt wedge. Depths range from one to twelve meters. Deltas usually form at the stream mouths. High flow streams have sand substrates and those with low flow normally have mud underlain by sand.

Salinity regimes are the major influences on the typically variable biota. Species range from freshwater to those found in medium-salinity or river-influenced bays. Again these systems are most common in Louisiana and become less significant as one moves south along the Texas coast. Figure 16, area 13.

Beach/upper shoreface

Salinity is relatively constant (20,000-35,000 ppm) with local variations near passes and inlets. Turbidity is high because of wave action. Temperature varies seasonally with a range of 9 - 35°C. Organic concentrations are generally high because of importation. Strong longshore currents are characteristic and vary seasonally--influenced by wind generated wave action. Rip currents are common. The bottom slopes gently toward the Gulf and always has a series of shifting bars with a substrate of coarse to fine well-sorted sands.

Low primary productivity is characteristic and dependent upon imported organic material. Diatoms and blue-green algae occupy the interstitial water spaces in the sand grains, and phytoplankton are abundant in the water column. Larger species live in or on the sediments and feed on interstitial species or filter organic materials. Many fish and birds feed on the benthic species. Figure 16, area 14.

Wind-tidal flats

The chemical characteristics of wind-tidal flats are typical of nearby medium-salinity, restricted, or hypersaline bays or lagoons. Temperature extremes result from intermittent water coverage, and when the area is inundated, the typical shallowness results in very hot temperatures in summer and cold extremes in winter. Turbidity ranges from clear to very turbid, and high dissolved and particulate organic material concentrations are normal. Wind is responsible for most of the water movement which is usually perpendicular to the shore. Water mixing is good and currents are low to moderate in intensity. Depths range from -30 to +60 cm mean sea level. These areas occur on the lee sides of barrier islands, near the mouths of intermittently flowing streams and creeks, and around the margins of hypersaline bays and lagoons. The areas tend to be long and narrow with substrate undulations and complex water movement patterns. Sands predominate, but in sheltered or depressed areas they may be muddy. Substrates are normally rich in organics and are often laminated with layers of blue-green algal mats.

Large infaunal forms or small interstitial water dwellers that burrow in the sediments make up the majority of the permanent residents. They are usually deposit feeders, filter feeders, or scavengers. Omnivores and carnivores migrate into and out of the area. There may be a great deal of primary productivity on the flats which are also dependent to a large degree on imported organic material. These areas are very common on the Texas coast, especially in areas of the upper and lower Laguna Madre. Figure 16, area 15.

Tidal marshes

Waters from medium-salinity bays, river-influenced bays, tidal stream reaches and restricted bays periodically inundate tidal marshes. These marshes are efficient nutrient-traps because of the action of the sediments and flora. Decaying marsh plants provide high concentrations of dissolved and particulate organic material. Turbidity and temperature vary considerably because of the shallow depth. Salinities vary from fresh to fairly saline depending on location. Tidal channels are common within the systems and water flow may be swift within these, but tends to be slow over the marsh itself. Salt marshes generally have diurnal flushing, while brackish marshes flood at periods of high tide, storm surge, and heavy rainfall. Oxygen depletion can occur if flushing is not frequent.

Depth normally ranges from mean low tide to about 1 meter above mean low tide. Brackish marshes and fresh-to-brackish marshes are low areas which occur inland of bays. There is no characteristic basin shape, except for water flow channels, and the marshes are usually connected to bay systems by constricted or shallow openings. The substrates range from sand to silt.

The most obvious characteristic of tidal marshes is the highly productive vegetation. Live plant material is usually not directly utilized by organisms--rather the decayed materials are consumed after bacterial action. Small invertebrates utilize the decayed material, and are in turn fed upon by a second level of consumers. Few carnivores are permanent residents of the system; they tend to be juvenile stages of various species that use the area for nursery grounds and then leave after several weeks. This emigration is the principal means of indirect export of organic material. In some fresh-to-brackish marshes, organic matter may collect for long periods before being washed out by seasonal floods or high water conditions. Louisiana is characterized by more fresh-to-brackish marshes, while the Texas coast tends to exhibit an increase in salt marsh systems as one goes from the upper coast to the Mexican border. Figure 16, area 16.

Washover channel complex

These areas are generally from 0 to 2 meters above mean sea level. Washovers are usually narrow and connect bays or lagoons directly to the Gulf over the barrier islands during times of very high water. They may be relicts of natural passes or may be formed by breaching of the sand dune line by high water. The substrate may be sand or mud, and in depressed areas saltwater or freshwater ponds are often formed with marsh vegetation. Organic material may collect from the vegetation, and nutrients may be collected from groundwater or local runoff. Moisture levels in the substrate range from 4 to 20 percent, making the area stable compared to the active dune complex. Temperature can be very high during daytime. Salt levels can become extremely high because of evaporation.

Plant growth can be limited by high salt concentrations, but in some cases plants do very well. On the flat areas, animal species are typically burrowing crustaceans and sand dwellers similar to those found in the dunes and higher parts of the beach. Pond species may be producers, herbivores and predators as would be found in saltwater and freshwater marshes. These areas are uncommon in Louisiana, but are predominant from St. Joseph's Island to the southern tip of Padre Island in Texas. Figure 16, area 17.

Active dune complex

This system is characterized by sparsely vegetated sand that tends to migrate with wind action. The sand is derived from the upper beach and/or old dunes that were once stabilized, but have been devegetated by drought, fire, overgrazing or human activity. Heights may range up to 15 meters on well-vegetated dunes. Dunes tend to align themselves perpendicularly to the predominant wind direction. Blowouts are common occurences and result from loss of vegetation on the foredune. The blowout may extend from the beach far across the island until the blowout field is stabilized. Ponds, bays and lagoons can be filled with these wind transported materials.

The substrate of the complex is beach-derived fine to very fine sand deficient of minerals. The dune sands are low in organic matter, highly permeable, have low moisture content, and are subject to high temperatures during the day. These characteristics make it difficult for rooted plants to take hold and for animals to dig burrows. Low nutrient concentrations add to plant growth problems. The blowing sands are very abrasive, and species living in the dune complex must be able to withstand high temperatures and dessication. Many of the species found in these areas are transients and reside in adjacent areas. Figure 16, area 18.

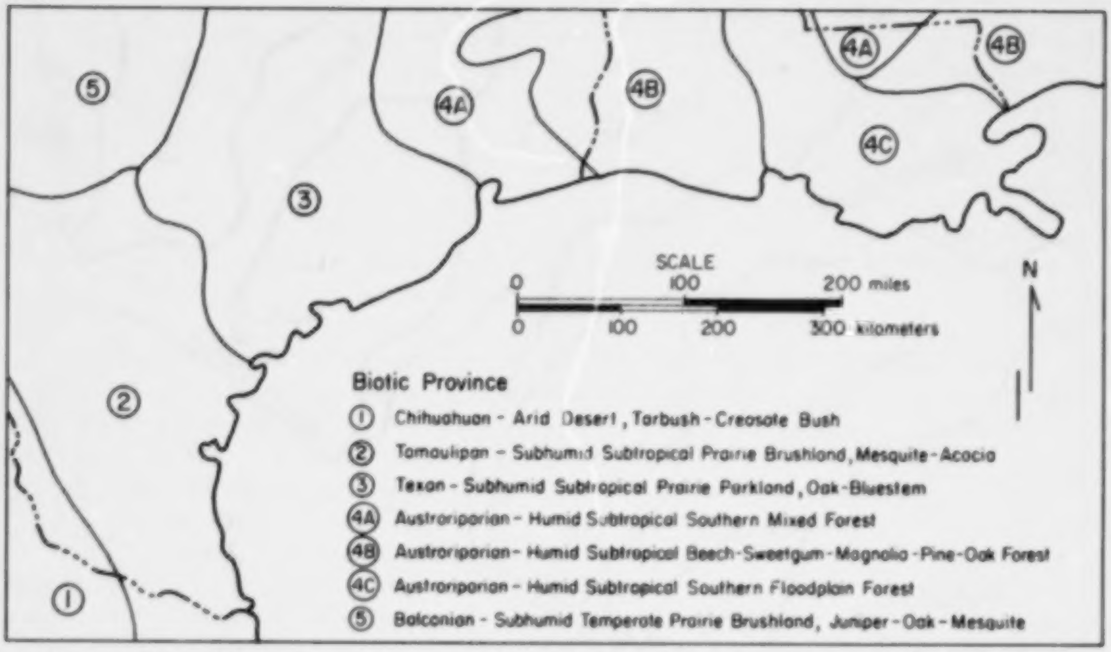
TERRESTRIAL AND FRESHWATER ECOLOGICAL ZONATION

Ecological and biogeographical zones

As mentioned previously, the study area includes four major terrestrial and freshwater ecological and biogreographical zones. These zones reflect not only the present ecological distributions of species, but also their evolutionary history. The patterns are evident from studies of plants (Tharp, 1939), historic American Indian groups (Kroeber, 1939), other terrestrial vertebrates (Blair, 1950), and freshwater fishes (Hubbs, 1957). Three major North American biotas are represented. Many of the plants and animals characteristic of the New World tropics enter the southern area on the Rio Grande plain. Species characteristic of the arid southwestern deserts are present in the extreme southwestern part of the study region. Plants and animals of the eastern humid coastal plain forests occupy the eastern section. These biotas interdigitate and intermix in characteristic groupings across the study area.

Parts of four biotic provinces recognized by Blair (1950) are represented (Figure 17). The Chihuahuan province is barely represented in southwestern Starr County, Texas. It includes species that are widely distributed in the deserts of southwestern North America. The Tamaulipan is subhumid subtropical prairie brushland dominated by Mesquite (Prosogis spp.) and Acacia (Acacia spp.) which includes the Gulf coastal plain extending from Mexico to approximately Calhoun County, Texas. The province contains a mixture of New World tropical species, eastern forest species and others characteristic of the southwestern deserts. The Texan province to the north is a broad ecotone (transitional ecological zone) which is a subhumid subtropical prairie parkland characterized by oaks (Quercus spp.) and bluestem (Poaceae). It is a transition area between the semi-arid grasslands to the west and the eastern mesic forest. Interdigitation of forest and grassland associations and species characterize this zone. The Austroriparian province includes humid subtropical forests of east Texas and southern Louisiana. Most of the species of this coastal plain forest region extend eastward to the Atlantic. Bailey (1976) recognizes three major subsections of the Austroriparian which are included in the study area: 1) a mixed forest present in the western part of the Austroriparian in Texas and the northern part of the toe of Louisiana, 2) Beech (Fagus grandifolia)-Sweetgum (Liquidambar styraciflua)-Magnolia-(Magnolia spp.)-Pine (Pinus spp.)-Oak (Quercus spp.) forests present in extreme east Texas and the western part of southern Louisiana and part of the toe of Louisiana north of the Mississippi delta, and 3) flood plain forest characteristic of the Mississippi valley and delta.

The above distributional pattern is exhibited by most species of freshwater fishes. There are two major exceptions: 1) those species limited by stream divides, and 2) associations of marine and freshwater forms living in freshwaters near the coast (Hubbs, 1957). The major stream divides, which affect 35 species of freshwater fishes in Texas, are the Rio Grande-Nueces, Nueces-Guadalupe, Brazos-Trinity, Trinity-Neches, and the Neches - Sabine (Figure 18). There are populations of the River Darter (Hadropterus) in the Guadalupe system which are disjunct from other populations in east Texas. And there are populations of the Suckermouth Minnow (Phenacobius mirabilis) in the Colorado drainage


⑤
(4A)
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SCALE
0
100
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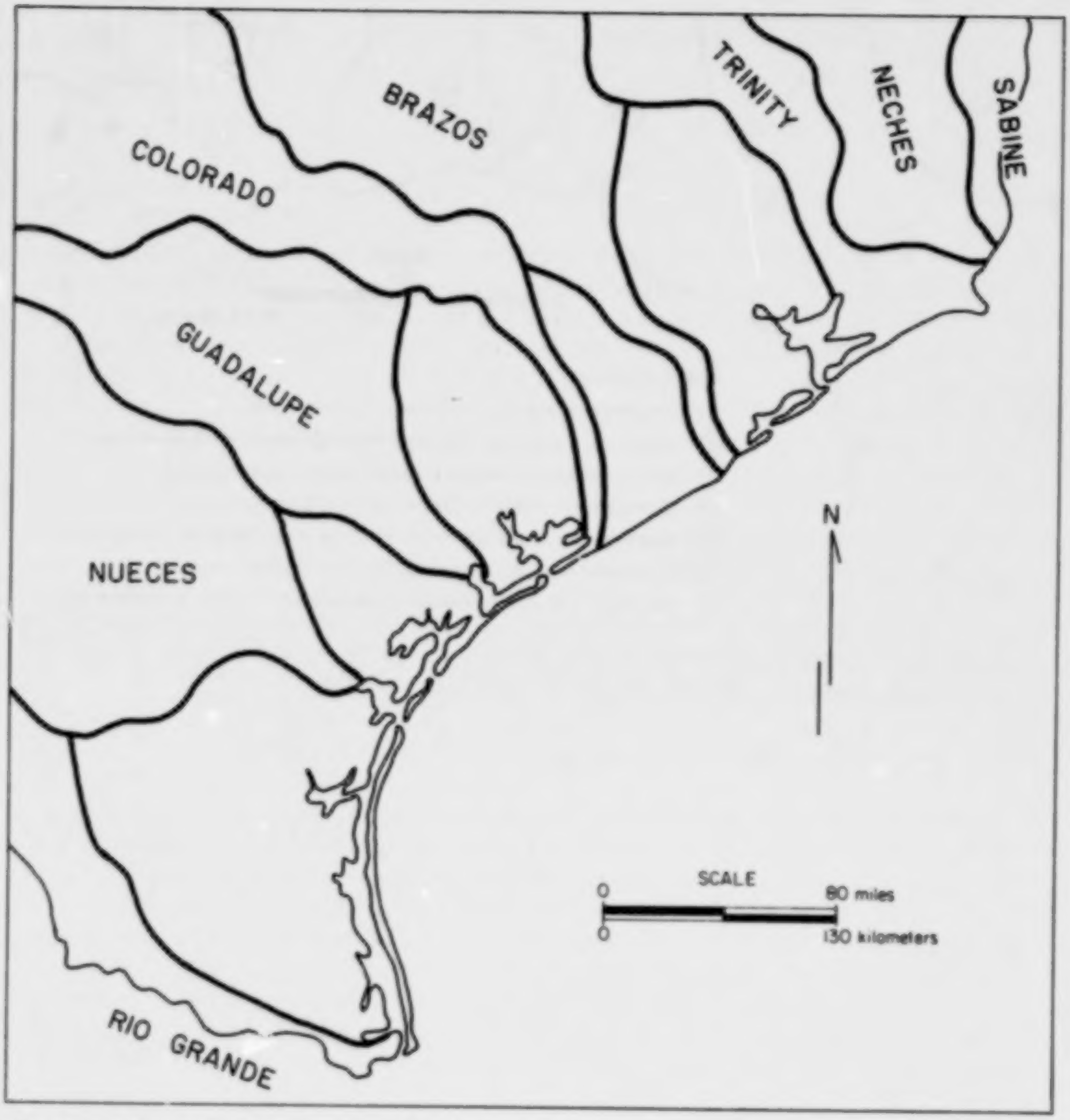
①
Biotic Province
① Chihuahuan - Arid Desert, Tarbush - Creosote Bush
② Tamaulipan - Subhumid Subtropical Prairie Brushland, Mesquite - Acacia
③ Texan - Subhumid Subtropical Prairie Parkland, Oak - Bluestem
(4A) Austroriparian - Humid Subtropical Southern Mixed Forest
(4B) Austroriparian - Humid Subtropical Beech - Sweetgum - Magnolia - Pine - Oak Forest
(4C) Austroriparian - Humid Subtropical Southern Floodplain Forest
⑤ Balconian - Subhumid Temperate Prairie Brushland, Juniper - Oak - Mesquite

Figure 17. Biotic provinces and ecological zones of coastal Louisiana and Texas. Based on Blair (1950) and Bailey (1976).


BRAZOS
TRINITY
NECHES
SABINE
COLORADO
GUADALUPE
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RIO GRANDE
N
SCALE
0
80 miles
0
130 kilometers

Figure 18. Major stream drainages of the Texas coastal zone. Based on Hubbs (1957).

which are widely separated from other populations in northeast Texas.

Kroeber (1939) indicated that the Caddo and Atakapa Indians were restricted primarily to the Austroriparian biotic province, the Karankawa inhabited the coastal prairie west of the Austroriparian, and the Tamaulipan biotic province was inhabited by Coahuiltecan Indians.

The broad biogeographic patterns illustrate not only differences in the ecological characteristics of the environments, but also genetic differences of the populations inhabiting them. When making predictions of possible environmental modifications such as those associated with energy exploitation strategies, these different areas must be considered separately. Hubbs (1957) notes that the agreement between the distributions of aquatic and terrestrial species is probably based on climatological and geological factors which probably determine the properties of water. He mentions difficulties in rearing Austroriparian fishes in waters of Balconian origin which have moderate amounts of dissolved salts and proportionally more calcium, magnesium and carbonate ions. There are similarly high mortalities of Balconian species in waters with low pH. This illustrates not only differences in ecology and physiology of species from different biogeographic areas but also the importance of ionic composition of water for fish.

COMMUNITY AND HABITAT DIVERSITY

Within each of the broad ecological zones discussed, there is a considerable diversity of habitat types and biological communities. The recently published or soon to be published maps of "biological assemblages" included in the Environmental Geological Atlas of the Texas Coastal Zone include 30 different physiographic types based primarily on plant associations and geological features (Fisher *et al.*, 1972, 1973; McGowen *et al.*, 1976 a, b; Brown *et al.*, 1976 and in press). Between 12 and 22 different "subaerial" biotopes are indicated for each of 7 mapped areas. The numbers and kinds of biotopes from the different areas may be compared in Table 5. This table illustrates the relationship of this variation to the biotic provinces included. Table 6 allows comparison of the change in numbers of species of three vertebrate classes among four biotic provinces. The more arid provinces have fewer amphibians and more reptiles and mammals. There are also marked changes in types of species of each class among the four provinces which are not obvious in Table 6. Harcombe (1974) thoroughly discusses communities of Chambers County, Texas. Watson (1975) gives an account of nine biological communities for parts of east Texas included in the Big Thicket National Preserve. Johnston (1955) contains much information on the plant

Table 5. Biological assemblages of seven map units of coastal Texas as documented in the Environmental Geologic Atlas of the Texas Coastal Zone.*

	Beaumont-Port Arthur	Houston-Galveston	Bay City-Freeport	Port Lavaca	Corpus Christi	Kingsville	Brownsville-Harlingen
Beach	+	+	+	+	+	+	+
Unvegetated coastal mud flat	+	−	−	−	−	−	−
Vegetated strandplain flat	+	−	−	−	−	−	−
Grass and locally scrub oak-covered ridges	+	−	−	−	−	−	−
Salt water marsh	+	+	+	+	+	−	+
Brackish water marsh	+	+	−	−	−	−	−
Brackish to fresh water marsh	+	+	+	+	+	−	+
Inland fresh water marsh	+	+	+	+	+	+	+
Prairie grasslands	+	+	+	+	+	+	+
Swamp	+	+	+	+	+	−	−
Frequently flooded fluvial areas	+	+	+	+	+	−	+
Fluvial woodland	+	+	+	+	+	+	+
Mixed pine and hardwood forest	+	+	−	−	−	−	−
Small prairies in forested uplands	+	+	−	−	−	−	−
Oak mottes and groves	+	+	+	+	+	+	+
Vegetated barrier flat	−	+	−	+	+	+	+
Sand flat	−	+	+	+	+	+	+
Barren land	−	+	+	+	+	−	−
Shell ramp barrier flat	−	−	+	−	−	−	−
Fluvial grassland	−	−	−	+	+	−	−
Berms	−	−	−	+	+	+	+
Washover channel and fan	−	−	−	−	+	+	+
Active dunes	−	−	−	−	+	+	+
Active clay-sand dunes	−	−	−	−	+	+	+
Poorly drained depressions	−	−	−	−	+	+	+
Loose sand and loess prairies	−	−	−	−	+	+	+
Brushland	−	−	−	−	+	+	+
Intense wind-deflation and wind-tidal activity	−	−	−	−	−	+	+
Fluvial brushland	−	−	−	−	−	−	+
Brush-covered bottom lands	−	−	−	−	−	−	+
Saline grasslands	−	−	−	−	−	−	+
TOTAL number of biotopes	15	15	12	14	20	15	21

+ *Biotope occurs in a particular mapping region.*

− *Biotope does not occur in a particular mapping region.*

| *Approximate coincidences with boundaries between biotic provinces as designated by Blair (1950): The boundary between the Houston-Galveston and the Bay City-Freeport sheets is somewhat south and west of the boundary between the Austroriparian and Texan biotic provinces. The boundary between the Port Lavaca and the Corpus Christi sheets lies southwest of the Texan/Tamaulipan boundary.*

Source: Fisher *et al.*, 1972, 1973; McGowen *et al.*, 1976a, b; Brown *et al.*, 1976 and in press.

Table 6. Numbers of species of three vertebrate classes among four biotic provinces of coastal Texas. The figures for the Chihuahuan are in parenthesis because the ranges of many of these species may not extend into the part of the Chihuahuan that is included in extreme south Texas.

	Amphibians	*Reptiles*	*Mammals*	*Total*
Chihuahuan	(14)	(61)	(83)	158
Tamaulipan	22	57	61	140
Texan	23	57	49	129
Austroriparian	35	41	47	123

*Based on Blair (1950).

associations of the southern coastal plain of Texas.

The above discussion indicates the importance of investigating diversity on a local scale and suggests the necessity of detailed planning efforts for human activities in such areas in order to fully understand ecological effects arising from these activities.

SPECIAL BIOLOGICAL RESOURCES OF THE LOUISIANA AND TEXAS COASTAL ZONE

MAJOR FISH AND WILDLIFE ECONOMIC RESOURCES

Forestry

Forestry is a major industry in the upper Texas coastal zone and southern Louisiana. There are many species of valuable natural hardwood trees in the area, the woods of which are suitable for a variety of uses. Much of the study area has been cut over at one time or another, and recent practice by the forestry industry has been to replace natural mixed forests of hardwood and pine with monoculture stands of single species such as slash pine (*Pinus elliotti*) used for pulp by the paper industry. The damaging ecological consequences of such management practices are now well-known. Both the natural forests and forest plantations are valuable economic resources, but the latter are much less suitable for wildlife (Gunter, 1971; Blevins and Novak, 1975). Most of the forested areas lie outside of the principal areas identified for possible geopressured-geothermal resource exploitation.

Fisheries

Freshwater--

The freshwater streams, lakes and ponds of the Texas-Louisiana coastal zone produce a wide variety of important sports fishes. Important species common to both Texas and Louisiana include: Largemouth Black Bass (*Micropterus salmoides*); various sunfishes, especially Bluegill (*Lepomis macrochirus*); White Bass (*Morone chrysops*); Black Crappie (*Pomoxis nigromaculatus*) and White Crappie (*P. annularis*); several species of catfish (Ictaluridae); Buffalofish (*Ictiobus* sp.); Carp (*Cyprinus carpio*); Freshwater Drum (*Aplodinotus grunniens*); Bowfin (*Amia calva*); and gars (*Lepisosteus* sp.). In addition, Louisiana fishermen often take chain Pickerel (*Esox niger*), Redfin Pickerel (*Esox americanus americanus*); Striped Bass (*Morone saxatilis*); Spotted Bass (*Micropterus punctulatus*); Paddlefish (*Polyodon spathula*); and an occasional Atlantic Sturgeon (*Acipenser oxyrhynchus*).

The major freshwater fishery in the coastal zone is the Louisiana crawfish industry which produces 99 percent of the annual United States harvest and is valued at some $6 million (de la Bretonne and Fowler, 1976). The most productive areas for the industry are the Atchafalaya Basin and Barataria Bay fresh swamp marsh. Pond crawfish farming is also prevalent.

Blue Catfish (Ictalurus furcatus) and Channel Catfish (I. punctatus) are also important commercial species and are taken from natural fresh waters with few restrictions. The annual harvest is approximately 182,000 kg. (U.S. Army Corps of Engineers, 1974). Channel Catfish (I. punctatus) are also raised in intense pond culture.

So called "rough" fish species are commercially netted by special permit in some areas. These are generally Carp (Cyprinus carpio); Drum (Aplodinotus grunniens); and Shad (Dorosoma cepedianum and Signalosa petenensis).

Few sports fishes are allowed to be taken for commercial purposes. Several species of turtle and Atlantic Sturgeon (A. oxyrhynchus) are harvested in Louisiana, but the sizes of catch are small compared to those of the other species mentioned above.

Estuarine--

The estuarine sports fishery is an extensive and year-round activity along the Gulf Coast. It is difficult to present actual numbers for this fishery because production from coastal waters is not distinguished on the basis of catch area. Fishes caught offshore, nearshore and in the estuaries are all considered part of the coastal catch. The major species sought by estuarine sports fishermen are: Redfish or Red Drum (Sciaenops ocellata); Speckled Seatrout or Spotted Seatrout (Cynoscion nebulosus); Black Drum (Pogonias cromis); Flounder (Paralichthys lethostigma); Atlantic Croaker (Micropogon undulatus); and Gafftopsail Catfish (Bagre marinus). In addition sportsmen take shrimp (Penaeus sp.) for bait and food, crabs (Callinectes sapidus and Menippe mercenaria); oysters (Crassostrea virginica and Ostrea equestris) and some species of clams (Pelecypoda).

The commercial fishery in the estuarine waters is predominantly involved with shellfish. Shrimp, oysters and crabs are taken in large quantities all along the coast. A new clam industry has recently begun operation in the Louisiana area as supplies of East Coast clams have either dwindled, or waters where they are abundant have been closed due to contamination. Shellfish harvest areas are under strict control by state agencies. Controlled fish netting (gill and trammel nets) and trotline sets are allowed in most areas and produce moderately large quantities of Redfish, Speckled Trout, Flounder, and several nongame species. Gunter (1967) states that estuarine-dependent species make up 97.5 percent of the total commercial catch of the Gulf states, and this has resulted in the regulation of fishing methods (both sport and commercial) that might result in harm to the overall fishery.

Marine--

The marine sportfishery is composed of surf fishing, jetty fishing, nearshore small boat and party boat excursions, and the "deep" sea fishery. Common fish taken in the inshore areas are: Redfish (Sciaenops ocellata); Speckled Seatrout (Cynoscion nebulosus) and Sand Seatrout (C. arenarius); Black Drum (Pogonias cromis); Croaker (Micropogon undulatus); Pompano (Trachinotus carolinus); Bluefish (Pomatomus saltatrix); Spanish Mackerel (Scomberomorus maculatus); Sheepshead (Archosargus propatocephalus); Snook (Centropomus undecimalis); Whiting (Kingfish) (Menticirrhus americanus); Tarpon (Megalops atlantica) (although they have declined in recent years); and several species of shark. Nearshore fishermen take: Barracuda (Sphyraena barracuda); Bonito (Euthynnus alletteratus); Cobia (Ling) (Rachycentron canadum); Dorado (Dolphin) (Coryphaena hippurus); Jack Crevalle (Caranx hippos); Jewfish (Epinephelus sp.); Skipjack (Elops saurus); Spanish Mackerel (Scomberomorus maculatus); Cero Mackerel (Scomberomorus regalis); King Mackerel (Scomberomorus cavalla); Sailfish (Istiophorus platypterus); Red Snapper (Lutjanus campechanus); Spadefish (Chaetodipterus faber); Tarpon (Megalops atlantica); and sharks. The offshore boats go after the larger gamefish such as:White Marlin (Tetrapturus albidus); Blue Marlin (Makaira nigricans); Wahoo (Acanthocybium solanderi); Blackfin Tuna (Thunnus atlanticus); Yellowfin Tuna (Thunnus albacares); Mako Shark (Isurus oxyrinchus); and Sailfish (Istiophorus platypterus); they also bottom fish near "reef" areas for Red Snapper (Lutjanus campechanus) and Dog Snapper (L. jocu); Amberjack (Seriola sp.); and Warsaw (Epinephelus nigritus).

The industrial fish populations of the Gulf of Mexico have produced some of the largest landings in North America, a substantial portion of which have come from the waters of Louisiana and Texas. The most important of the products in terms of dollar value are the shrimps, accounting for 56% of the United States total of 171,926,690 kilograms (379,034,000 pounds) for the five year period of 1970 to 1974 (U.S. Department of Commerce, 1976). The Brown Shrimp (Penaeus aztecus), the White Shrimp (P. setiferus) and the Pink Shrimp (P. duorarum) are the most important commercial species in the Gulf of Mexico. The Sea Bob (Xiphopenaeus krogeri) and the Royal Red Shrimp (Hymenopenaeus robustus) have commercial status, but they make up a very small percentage of the shrimp caught in Gulf waters. Table 7 gives an indication of

Table 7. Acres of marshes, estuarine waters, and shrimp catch (heads-on) by states.*

	ACRES			*POUNDS*
	Estuarine Waters	*Coastal Marshes*	*Mangrove Swamps*	*Average Annual Shrimp Catch 1965-1974*
West coast of Florida	2,081,525	528,528	393,160	26,578,000
Alabama	397,353	34,614	--	14,035,000
Mississippi	500,379	66,933	--	8,063,000
Louisiana	3,378,924	3,900,000	--	73,547,000
Texas	1,344,000	486,400	--	83,744,000

*From Barrett and Gillespie (1975).

the total nursery areas contained in the Gulf Coast by state and the average annual shrimp catch. The relative catch of Brown, White, and Pink Shrimp for the Texas and Louisiana coasts are indicated in Figure 19. Shrimp productivity is dependent on the availability of coastal marshes which function as a nursery, refuge and a food source. The habitat requirements of juvenile shrimp have been discussed by Gunter (1961), Barrett and Gillespie (1973) and Gaidry and White (1973). The importance of salinity and freshwater runoff in the production of penaeid shrimp are reviewed by Gunter and Edwards (1969), Gunter *et al.* (1964), Zein-Eldin and Griffith (1969) and Copeland and Bechtel (1974). Aldrich (1964), Joyce (1965), Zein-Eldin and Griffith (1969), Williams (1960) and Copeland and Bechtel (1974) have discussed the temperature relationships for penaeid shrimp.

The major finfish exploited commercially is the Gulf Menhaden (*Brevoortia patronus*). It has been reported to support the largest commercial fishery in North America (Reintjes and Pacheco, 1966). Gunter and Christmas (1960) reviewed the Menhaden fishery and found that approximately 70 percent of the production came from Louisiana. In addition to the Menhaden fishery there is an industrial bottom fishery which is relatively new to the northern Gulf. The seasonal composition of this bottom fishery has been investigated by Thompson (1959a, 1959b, 1959c). The Bay Anchovy (*Anchoa mitchilli*); Atlantic Croaker (*Micropogon undulatus*); Largescale Menhaden (*B. patronus*); Atlantic Threadfin (*Opisthonema oglinum*); and Spot (*Leiostomus xanthurus*) are estimated to make up 90 percent of the commercially classified species (Lyles, 1965). The bottom fish industry for the northern Gulf of Mexico from 1959 to 1963 was summarized by Roithmayr (1965). Dunham (1972) conducted a study of commercially important estuarine-dependent industrial fishes. It has been estimated that over 90 percent of the total commercial catch of finfish and shellfish in the Gulf of Mexico are estuarine-dependent (Louisiana Wildlife and Fisheries Commission, 1971). With the exception of the Menhaden (*B. patronus*) and to some extent the Atlantic Croaker (*M. undulatus*), the majority of the finfish taken by industrial bottom fishermen are so called "trash fish" and are useful as a source of fish meal.

There is a relatively minor beach sein fishery in the Gulf Coast region. The major species taken by this method are Redfish (*Sciaenops ocellata*); Speckled Trout (*Cynoscion nebulosus*); Flounder (*Paralichthys lethostigma*); Black Drum (*Pogonias cromis*); White Mullet (*Mugil* curema); and Striped Mullet (*M. cephalus*). Longline fishermen fish for tuna in the deeper offshore waters, but in the process catch billfish and sharks of various species.

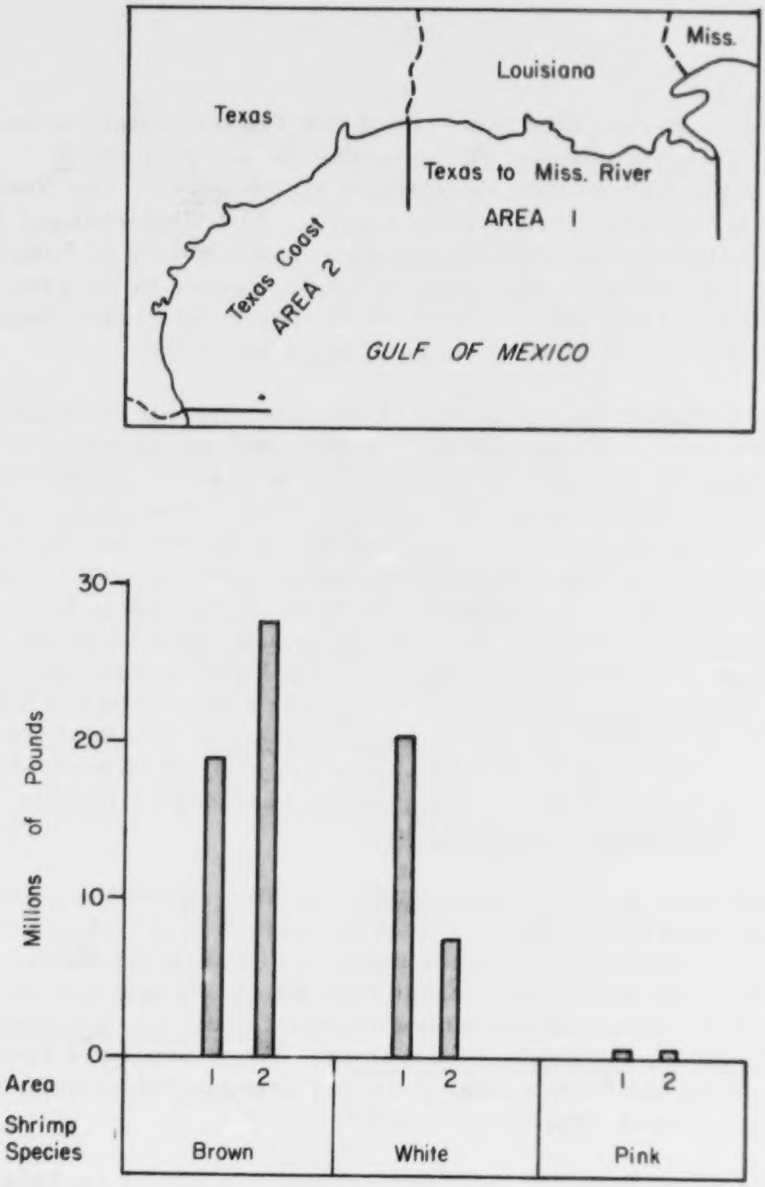


Figure 19. Location and average annual shrimp catch by species in the Texas-Louisiana coastal waters for the period 1958-1971. Adapted from Barrett and Gillespie (1975).

Game birds

Upland game birds--

The major upland game birds along the Texas-Louisiana coast are Wild Turkey (Meleagris gallopavo), Mourning Doves (Zenaidura macroura), and the Bobwhite Quail (Colinus virginianus). The Woodcock (Philohela minor) is hunted to a lesser degree. The White-winged Dove (Zenaida asiatica) is hunted in the lower Rio Grande valley of Texas in Cameron, Hidalgo, Kenedy, Starr and Willacy Counties in the areas of projected geothermal fairways. All of these species are under regulatory and management controls of state fish and game agencies.

The Wild Turkey (M. gallopavo) is not abundant in Louisiana and is found mostly in the northeastern part of the state and in areas of the Florida Parishes. In Texas it is common on the coastal prairies from the central coast to the Rio Grande. The Wild Turkey is the largest upland game bird of the United States. Its preferred habitat is a wooded area with scattered openings. Major foods are nuts, berries, seeds, insects, cactus "apples" (Optuntia lindheimeri), vetches (Vicia spp.), Mexican Persimmon (Diospyros texana), Wild Pea (Vigna luteola), Anacua (Ehretia anacua), Pecans (Carya illinoinensis), Wild Grapes (Vitis spp.), and Agarito (Berberis trifoliolata). The eggs are subject to predation from snakes, Roadrunners (Geococcyx californianus), and Racoons (Procyon lotor). The adult birds and chicks are subject to predation by Coyotes (Canis latrans), Bobcats (Lynx rufus), and eagles (Aquila chrysaetos and Haliaeetus leucocephalus).

The Bobwhite Quail (C. virginianus) is often called the number one game bird of eastern and southern United States. It is mainly a farm land game bird. The ideal habitat is a combination of cultivated fields, brush and weed patches and wood lots. Major food items are insects, seeds, buds, and berries. Common predators are the Coyote (C. latrans), snakes, and skunks (Mephitis, Spilogale, Conepatus). These birds are very common throughout the Gulf coastal plain and abundant on barrier islands where human population densities are low.

The Mourning Dove (Zenaidura macroura) is one of Louisiana's commonest permanent residents and the most widespread wild dove in Texas. It occurs throughout the two states and occupies a variety of habitats ranging from farmlands, ranches, towns, Mesquite (Prosopis spp.) brushland, woodlands and open country to desert. Seeds of small grains and weeds are their main food source, but they will also take fruits and insects.

Migratory waterfowl--

The coastal areas of Texas and Louisiana provide vast areas for wintering of migratory waterfowl of the Central and Mississippi Flyways. Each year large numbers of geese (Anserinae), dabbling (Anatinae) and diving ducks (Aythyinae and Oxyurinae) make their way to the marshes, bays and estuaries of the Gulf Coast. U.S. Fish and Wildlife Service statistics for 1973 indicated that 6,568,900 ducks, 1,023,100 geese, and 1,893,600 Coots (*Fulica americana*) wintered in Texas and Louisiana (U.S. Department of the Interior, 1975). These figures represent 56% of ducks, 48% of geese, and 95% of Coots wintering in the entire combined Central and Mississippi Flyways. These figures alone emphasize the importance of these areas in the maintenance of waterfowl populations not only in these states, but for the entire nation.

The dabbling ducks (or puddle ducks, Anatinae) are the most abundant species wintering in the Texas-Louisiana area. The major species in order of abundance are: Mallards (*Anas platyrhynchos*), Pintails (*A. acuta*), Gadwall (*A. strepera*), Green-winged Teal (*A. carolinensis*), American Widgeon (*Mareca americana*), Northern Shoveler (*Spatula clypeatra*), Blue-winged Teal (*A. discors*), Black Ducks (A. *rubripes*), and Mottled Ducks (*A. fulvigula*). These ducks are typically birds of fresh shallow marshes and rivers rather than of large lakes and open bays. Food is foraged under a shallow cover (5 to 15 cm) of water, and they cannot reach deep water bottoms. Their diet consists mostly of vegetation and they are often found in croplands; they are sure-footed and can walk and run well on land. At peak densities in the winter, dabbling ducks reach concentrations of 100 to 300 ducks per 100 acres in fresh and intermediate marshes.

The diving ducks (Aythyinae and Oxyurinae) frequent the larger, deeper lakes and rivers and coastal bays and inlets. At peak densities during the winter, they are present in concentrations one order of magnitude lower than the dabbling species. The diving species found in the Texas-Louisiana area in order of abundance are: Lesser Scaup (*Aythya affinis*), Redhead (*A. americana*), Ring-necked Duck (*A. collaris*), Canvasback (*A. valisineria*), Goldeneye (*Bucephala clangula*), Ruddy Duck (*Oxyura jamaicensis*), and the Bufflehead (*B. albeola*). These ducks feed by diving, often to considerable depths. Their diets consist of fish, shellfish, mollusks, and aquatic plants. Canvasbacks (*A. valisineria*) and Redheads (*A. americana*) take large quantities of Eel Grass (*Vallisneria americana*) and Wild Celery (*Apium leptophyllum*).

The Common (*Mergus merganser*), Red-breasted (*M. serrator*) and Hooded (*Lophotdytes cucullatus*) Mergansers also frequent the coastal zone, although their total numbers are low compared to most of the other species in the area. Coots are extremely common in both flyways.

Blue Geese (*Chen caerulescens*), Snow Geese (*C. hyperborea*), White-fronted Geese (*Anser albifrons*) and Greater Canadian Geese (*Branta canadensis*) are common in both flyways. Ross' Goose (*C. rossi*) occurs to some extent in the Central Flyway. Geese tend to be terrestrial-feeding, mainly in stubble fields and rice producing areas. They are commonly seen flying between feeding areas and grassy marshes in the mornings and evenings.

Waterfowl require at least three things from their habitat: food, water, and refuge. Ducks require open waters for landing, taking off, and resting. Small marsh ponds are ideal for these purposes since they provide refuge from winds and storms. Marshes with many small ponds provide much better waterfowl habitat than solid grass stands. Large reserve areas such as the Aransas National Wildlife Refuge and the Brazoria Refuge in Texas and the Sabine and Rockefeller Refuges in Louisiana serve to allow parts of waterfowl populations to escape harvest and maintain themselves.

The population levels of migrating waterfowl are dependent on several factors. Points of major concern are the conditions for nesting and food availability in the northern breeding grounds. In the wintering areas, water levels are critical as well as the availability of food both in marshes and in the surrounding fields and croplands. Management techniques currently employed in these areas are concerned principally with controlling water levels to provide optimum depths for foraging of dabbling ducks, the promotion of appropriate feeds, and suitable open water areas for resting and refuge. Impounded areas are either drained or flooded to allow proper levels for germination of annual grasses.

Waterfowl harvest regulations are selected by the Texas Parks and Wildlife Department and the Louisiana Wildlife and Fisheries Commission from a set of options provided by the U. S. Fish and Wildlife Service. The Fish and Wildlife Service options are based on summer breeding ground surveys, migration data, and overwintering of waterfowl within the various Texas and Louisiana habitats. Total harvest for the combined Central and Mississippi Flyways for 1972 amounted to 8,020,400 ducks, 728,400 coots, and 594,900 geese (U.S. Department of the Interior, 1975).

Marsh birds--

Marsh birds that are hunted less frequently than the above game birds are King Rail (*Rallus elegans*), the Clapper Rail (*Rallus longirostris*), the Virginia Rail (*Rallus limicola*), the Ora (*Porzana carolina*), the Common Snipe (*Capella gallinago*), the Woodcock (*Philohela minor*) and the Common Gallinule (*Gallinula chloropus*).

Non-game birds

The geographical position of the Texas-Louisiana coastal zone within the Central and Mississippi Flyways is an area through which millions of birds wing their way twice a year during their annual migrations. In addition to the game species already mentioned, passerines, raptors, wading birds and various sea birds spend all or a portion of the year in the coastal zone. The southern location affords a mild climate favorable for wintering many northern species, and there are also many residents. Many of the migrants become concentrated on the Gulf Coast by the physical barrier of the open waters of the Gulf. The number of species of birds recorded for Louisiana is 377 (Lowery, 1960) and for Texas 532 (Wolfe *et al.*, 1974). Although these figures are for the entire states, many of the species are found in the coastal areas.

The coastal prairies of the region support large flocks of grackles (*Cassidix mexicanus* and *Quiscalus quiscula*) and other blackbirds (Icteridae) in late summer and autumn. Herons, egrets, ibises (Ciconiiformes) and, in winter, Sandhill Cranes (*Grus canadensis*) are also present in large numbers. In summer the coastal prairies provide nesting habitat for such species as Attwater's Greater Prairie Chicken (*Tympanuchus cupido attwateri*), Florida Common Nighthawk (*Chordeiles minor*), Texas Horned Lark (*Eremophila alpestris*), and Southern and Rio Grande Eastern Meadowlarks (*Sturnella magna*) (Robbins *et al.*, 1966; Oberholser, 1974).

Fresh and salt marshes of the area support great flocks of blackbirds and grackles (Icteridae) and smaller numbers of other birds in fall and winter. Birds that breed in these marshes and are for the most part confined to them include: White Faced Ibis (*Plegadis chihi*), Fulvous Tree Duck (*Dendrocygna bicolor*), Mottled Duck (*Anas fulvigula*), Purple Gallinule (*Porphyrula martinica*), Louisiana Long-billed Marsh Wren (*Telmatodytes palustris*), Gulf Coast and Rio Grande Red-winged Blackbirds (*Agelaius phoeniceus*), Boat-tailed Grackle (*Cassidix mexicanus*, and Louisiana and Texas Seaside Sparrows (*Ammospiza maritima*). All except for the Seaside Sparrow prefer fresh marshes for nesting (Robbins *et al.*, 1966; Oberholser, 1974).

The sandy shores of the Gulf Coast commonly support large numbers of birds, especially during spring and autumn migrations. The beaches and sandy islands of the area provide breeding areas for many shorebirds and water birds among which are Brown Pelican (*Pelicanus occidentalis*), Olivaceous Cormorant (*Phalacrocorax olivaceus*), Reddish Egret (*Dichromanassa rufescens*), Roseate Spoonbill (*Ajaia ajaja*), American Oyster-catcher (*Haematopus palliatus*), Snowy Plover

(*Charadrius alexandrinus*), Wilson's Plover (*C. wilsonia*), Willet (*Catoptrophorus semipalmatus*), Laughing Gull (*Larus atricilla*), Gullbilled Tern (*Gelochelidon nilotica*), Forster's Tern (*Sterna forsteri*), Eastern Least Tern (*S. albifrons*), Royal Tern (*Thalasseus maximus*), Sandwich Tern (*T. sandvicensis*), Caspian Tern (*Hydroprogne caspia*), and Black Skimmer (*Rynchops nigra*). In these areas as in the coastal prairies and marshes, a number of northern breeders linger through the summer without nesting (Oberholser, 1974). The best known bird wintering on the Gulf Coast is the Whooping Crane (*Grus americana*), which is found at the Aransas National Wildlife Refuge during these cold months.

Many of the listed species are considered endangered or threatened, as previously discussed, by various state and federal agencies. The Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), and Eskimo Curlew (*Numenius borealis*) also frequent the coastal zone. These species and other birds are listed in Appendix C as endangered vertebrates of coastal Texas and Louisiana. Additional species which occur in the area are documented in Lowery (1960) for Louisiana and Wolfe *et al.* (1974) for Texas.

Game mammals

Three species of game animals are extensively hunted in the Gulf Coastal zone: the White-Tailed Deer (*Odocoileus virginianus*), the Eastern Fox Squirrel (*Sciurus niger*) and the Eastern Gray Squirrel or Cat Squirrel (*Sciurus carolinensis*). In addition two species of rabbit (Cottontail, *Sylvilagus floridanus* and Swamp Rabbit, *Sylvilagus aquaticus*), a hare (Black-Tailed Jackrabbit, *Lepus californicus*), the Collared Peccary or Javalina (*Tayassu tajacu*), the Black Bear (*Ursus americanus*), the Armadillo (*Dasypus novemcinctus*), the Coyote (*Canis latrans*), Russian Boar (*Sus scrofa*), the Raccoon (*Procyon lotor*), the Opossum (*Didelphis marsupialis*), Ringtail (*Bassariscus astutus*), and several species of wild cats are all hunted to a lesser degree.

White-tailed deer (*Odocoileus virginianus*)--

Deer inhabit many forested and brushy areas of the region. Highest population densities are found in areas which have a mixture of hardwood bottomland and pasture land. These population densities reflect quantity and quality of food and cover, as well as hunting pressure. Deer maintain a home range and rarely emigrate, even when food is scarce. Important food sources on forest boundaries are types of browse including timber sprout growth, shoots, twigs, and buds of shrubs. In eastern regions, fruits are equally important. Other important foods are mast (particularly acorns), herbaceous plants, mushrooms, fungi, and mosses. Although deer occasionally eat grasses, they normally make up only a small portion of the diet.

In addition to being an important food source, vegetation provides cover in which deer spend much of their daytime hours. Many types of forest and brush serve as cover. Deer habitat may include a combination of topography and vegetation such as trees, brush, ravines, hillslopes, stream courses, flat terrain, thickets or unbroken tracts of timber. Deer drink at least once a day, and habitat must therefore offer access to sources of open water. Water may be a serious concern for deer in the southern part of our study area during drought.

In the past, Gray Wolves (Canis lupus) and Pumas (Felis concolor) preyed upon deer in this area. Today man is their only significant predator.

Management techniques employed to maintain deer populations at reasonable levels include controlled hunting, planned clearing of forest and brush, and establishment of refuge areas. Deer are hunted throughout the Gulf Coastal zone. Control and management of hunting is carried out by the appropriate state wildlife agencies.

Certain forestry management practices of the region, particularly in the Austroriparian zone, reduce the quality of deer habitats. Many forested lands are managed almost solely for pine timber products. Increasingly, areas are clear-cut (all trees and brush are eliminated) and pure stands of Slash Pine (Pinus elliotti) are planted. Such a forest is of much less value to deer and other wildlife than one which has a variety of vegetation and a well-developed understory. In some areas, such as the hardwood forests of Brazoria County, deer habitats could be improved by clearing strips of land so that a brush understory could develop. Selective cutting and thinning to maintain a variety of vegetation can increase the amount of browse and cover. Such measures can increase the habitat carrying capacity for deer and somewhat compensate for losses which may result from other human activities.

Clearing of brush and forest to expand agricultural cultivation and to establish improved pasture for cattle plays a significant role in destruction of deer habitat in some areas. The extent of these practices in the region have not been determined. When such clearing is planned, wildlife managers recommend leaving strips of brush or forest undisturbed in order to conserve, and in some cases improve deer habitats.

The above account is based primarily upon Blevins and Novak (1975). That work contains additional information on the status of deer populations in this area. Other important references include Flader (1974), Rue (1962), Shoman (1966), Taylor (1956), and Tier (1969).

Squirrels (Sciurus)--

It has been estimated that 70 percent of licensed hunters in Texas take squirrels. In terms of measured numbers of hunting days, squirrels are the most important small game in the region (Blevins and Novak, 1975).

The geographic distribution of the Eastern Fox Squirrel (*Sciurus niger*) extends farther south and west than that of the Eastern Gray Squirrel (*S. carolinensis*). The Fox Squirrel is also highly adaptive and much more numerous than the Gray Squirrel within the range of the latter. The Gray Squirrel is more sensitive to land use changes and is decreasing throughout the part of its range included in the study area. At a number of localities, the more adaptable Fox Squirrel has replaced Gray Squirrel populations where detrimental land uses have modified Gray Squirrel habitat.

The status of a squirrel population depends on the quality of available habitat. For these animals habitat quality can often be measured by the number of mast-producing hardwood trees per unit/area. Large nonforested areas in the region have few or no squirrel habitats. The biotic provinces containing the largest amounts of favorable squirrel habitats are the Austroriparian and the Texan.

Prime Fox Squirrel habitat consists of open mixed hardwood forests with scattered small clearings and irregularly shaped groves connected by strips of trees. Gray Squirrels prefer a continuous forest of mature hardwoods with a dense understory of immature trees. Fox Squirrels easily adapt to changing environments and can survive in habitats consisting of isolated small groves or even isolated trees which are not too widely spaced. Therefore, they readily adapt to urban areas where trees are often scattered.

Both squirrels eat many types of foods including insects, green shoots, fruits, seeds, and buds of trees. Mast such as acorns (*Quercus* spp.), pecans (*Carya illinoinensis*) and hickory nuts (*Carya* spp.) are the principal elements in their diets. These species mate twice a year; during January-February and during May-June. They prefer to use dens in hollow trees, but they may also build nests in trees using leaves and twigs. These dens and nests provide protection from weather and predators.

Prime Gray Squirrel habitats have been significantly reduced because of grazing and extensive clearing of bottomlands. Forest modifications, such as strip clearing for pastures, which improve habitat for Fox Squirrels, create habitat less suitable for Gray Squirrels. Because of such activities, many Gray Squirrel habitats have been invaded by Fox Squirrels. If the Gray Squirrel is to continue to be an important wildlife resource in the area, its habitat must be recognized and preserved.

Few if any management practices are currently being utilized to maintain and improve squirrel populations. Clearing forests for agricultural purposes or forestry management practices that result in the removal of good mast-producing trees or den trees are detrimental. Girdling of hardwoods and clearcutting followed by planting of monocultural stands of pine are very destructive of squirrel habitats. Strip management and/or selective cutting, leaving many hardwoods undisturbed, is much less destructive to wildlife.

The above discussion is based primarily on Blevins and Novak (1975). Discussions of other aspects of squirrels' life histories in this area may be found in Blevins and Novak (1975), Barkalow and Shorten (1973), Davis (1966), Goodrum (1967), Rue (1968), and Shoman (1966).

Furbearers

The trapping industry in the Gulf Coast area is principally confined to the upper Texas coast and the Louisiana coast. The Nutria (Myocaster coypus) and the Muskrat (Ondatra zibethicus) are the major species exploited in terms of commercial value. Three other species are commonly taken, but to a lesser degree: Mink (Mustela vison), Nearctic River Otter (Lutra canadensis) and the Raccoon (Procyon lotor).

Nutria (M. coypus) are browsers that depend on marsh habitats for food. This is an introduced species, and it is now widespread in eastern Texas and Louisiana. They are rarely found in salt marshes and increase in numbers from brackish to intermediate marshes and are most abundant in freshwater marshes. Total pelt value for Louisiana-caught Nutria in the eight year period from 1968 to 1976 was about $45 million. They are also prized as a meat source in some areas of the state. Management practices currently used to improve Nutria harvest include the plowing of ditches in brackish marshes--making them more accessible to waterborne trappers. Nutria make use of high ground provided by natural and man-made levees in marsh bayous.

The Muskrat (O. zihethicus) occupies a niche similar to that of the Nutria. The brackish marsh is the Muskrat's preferred habitat, and they become less prevalent in intermediate and freshwater marshes. Muskrats occur in the salt marsh system. Brackish marshes are managed for Muskrats by burning and by water manipulation. The major food source of the Muskrat is Olney's Three Square (Scirpus olneyi), and management techniques are aimed at perpetuating stands of this grass in addition to controlling Muskrat populations at levels to prevent overgrazing of marshes. Pelt values for the 1968-1976 period amounted to over $10 million in Louisiana.

Trapping pressure on Raccoon (P. lotor), Mink (M. vison) and River Otter (L. canadensis) varies considerably and is dependent on the market value of the species. Mink pelt values have declined in recent years as a result of the high quality of ranch Mink furs. During the period of 1968-1976, an average of 6,693 otters were trapped each year in Louisiana with an average pelt value of $20 to $42. River Otter populations in east Texas are considered threatened by the Texas Organization for Endangered Species (1975). Raccoon trappings probably vary more than those for other species, and coastal pelts are less valuable than those caught upstate. They are also valued as a meat source bringing 20 to 30 cents per pound. There are no management practices currently being used to improve marsh areas for Raccoon, Mink and River Otter.

Unique, rare or endangered species

There are 228 species of plants and animals known from the coastal region which are rare and/or in danger of extinction. These include 154 plant species and 74 species of vertebrates. The latter include 22 mammals, 36 birds, 12 reptiles and 4 amphibians. Not all of these species are protected by law. Forty-two of the vertebrates are considered endangered, threatened, or rare by the U.S. Fish and Wildlife Service (Blevins and Novak, 1975; Rare Plant Study Center, 1974; Texas Organization for Endangered Species, 1975). An endangered status may result from one or several causes such as destruction of habitat, over-exploitation, predation, species competition, disease, or use of pesticides or other poisons. Most endangered species have narrow ranges of ecological tolerance and in the modern human-dominated world require special protection or management for their survival. Reasons for decline and the present sizes and distributions of populations must be determined in order to provide adequate protection.

The list in Appendix B is an assessment of plant species rare or threatened with extinction in at least the Texas coastal region and is derived from Rare Plant Study Center (1974). The species are arranged in three major vegetational areas which correspond approximately to biotic provinces: 1) east Texas; 2) coastal prairie; and 3) Rio Grande plains (Figure 20). Parts of some counties are in more than one area. Detailed distributional and ecological information on the species of plants in Appendix B beyond the data presented have not been determined for this study. It should be noted that such information on many species is not readily available in the published literature.

Appendix C presents information on the status, distribution, and ecology of endangered vertebrates of the study area. This information has been derived from Texas Organization for Endangered Species (1975). The status of the taxa contained are defined as endangered, threatened or peripheral. See Appendix C for explanations of uses of these terms. The present vertebrate list is cross-referenced with those of the Texas Parks and Wildlife Department and the U. S. Fish and Wildlife Service. Brief statements of distribution and preferred habitat in Texas and reasons for the assigned status are given. This list, the latest of several since 1972, was written between November, 1974 and March, 1975. Taxa may be added or subtracted, and the status of species or subspecies may change as further studies are made.

As part of the current study, a search was made of recent literature in the computer based file BIOSIS PREVIEWS, which is the computer version of Biological Abstracts, for each species of vertebrate in Appendix C. Many of these references are included in Appendix D. Both a bibliographic card file and a notebook file with records of the computer search are available for use at the Bureau of Economic Geology, the University of Texas at Austin.

AESTHETIC RESOURCES

The determination of aesthetic or social value is and has long been a problem. The concept varies with time as well as from group to group and among individuals. See Leopold (1966). Residents of and visitors to the coastal zone value abundant open space, a pleasant climate, and scenic areas (General Land Office of Texas, 1976). Diversity of land, water, and plant and animal life in natural areas that can sustain a variety of recreational uses rates high in most people's minds. Activities based on such resources may include hunting and fishing, nature study, painting and photography, experiencing solitude, transportation-based activites, environmental education and practicing of husbandry of natural systems. Resources that allow intensive uses in one place without affecting the scenic or other aesthetic qualities in another are of prime consideration.

The problem in assessing these noneconomic aesthetic resources arises when attempts are made to decide what they are worth. Both natural resources and economic activities can be quantified to one extent or another, but personal preferences tend to be much more meaningful in a political context than data on resources or economic values.

As an example of some of the factors which may adversely affect the aesthetic value of a coastal area, let us consider the wetlands. The quality of a bay or estuary may be adversely affected in a direct manner by any substances altering its appearance such as floating materials, unusual color, or high turbidity due to suspended solids. Likewise, unusual odors and tastes are undesirable. Significant changes, either natural or man-induced, in any biological process may be detrimental.

Air pollution and devegetation are also undesirable from an aesthetic point of view (Coastal Resources Management Program, 1972).

There are excellent opportunities for the enjoyment of aesthetic values in the coastal zone of Texas and Louisiana. Many such opportunities have decreased as population has increased. Industrial pollution, juxtaposition of incompatible land use activities and other actions have contributed to this (Blevins and Novak, 1975). But there is still an abundance of such resources, and careful planning is required to preserve them.

No parts of the area are presently included in the national wilderness system under the Wilderness Act. There are proposals to include portions of the Big Thicket National Preserve and approximately 80,000 additional acres in east Texas national forests in the wilderness system.

Most land in the coastal zone is under private ownership. Some landowners preserve natural resource values; others do not. Landowners sometimes resent efforts by the public to regulate land use activites on private property. Within such questions are serious dilemmas of resource conservation (Blevins and Novak, 1975; General Land Office of Texas, 1976).

POTENTIAL EFFECTS OF GEOTHERMAL ENERGY EXPLOITATION ON THE ECOLOGY OF THE TEXAS-LOUISIANA GULF COASTAL REGION

Consideration of possible environmental impacts of geopressured-geothermal energy exploitation at this time is somewhat speculative because of several unknown or undecided factors. For example, complete water analyses are not available for geopressured fluids, several potential locations of fields in different coastal environments are being considered, and several alternative thermal-electric conversion technologies are possible. Krause (1976) discussed the need to compare environmental impacts of onshore and offshore strategies, and he proposed ecological assessment of potential geopressured energy activities which would meet the following objectives:

(1) Determine impacts of onshore strategies in terms of loss of recreational and public lands (marsh and estuarine resources), fish and wildlife conservation, subsidence, drainage, flood control and salt water intrusion.

(2) Determine impacts of offshore activities resulting from disposal of drilling muds, uptake of cooling waters and disposal of spent fluids into the ocean.

(3) Recommend optimum combinations of onshore and offshore sites that would minimize negative impacts.

(4) Accelerate evaluation of geopressured-geothermal energy resource exploitation by coordinating use of results of ongoing studies assessing onshore activities, secondary stimulation of oil and gas reservoirs, offshore oil and gas leases and construction of nuclear power plants.

There are no geopressured wells currently being used for geothermal production, much less a full scale electrical generating geopressured field. Because of some similarities between geothermal steam, geothermal normal pressured, and oil and natural gas exploitation characteristics, we make comparisons between these systems and potential geopressured ones. We try to specify both similarities and differences between geopressured systems and these others.

Potential location scenarios

Geopressured reservoirs may be located beneath several types of coastal environments including: the Gulf of Mexico, estuaries, bays, lagoons, wetlands, barrier islands, or uplands. See Phase I of this report (Gustavson and McGraw, 1977).

The following general location scenarios are considered:

(1) Production, generating and disposal facilities on coastal land where access would be by roads.

(2) Generating, production and disposal facilities on low lying coastal marsh; this might require access by dredged canal. These areas occur primarily east of the Sabine River.

(3) Production facilities offshore in estuaries, bays, lagoons, coastal lakes or in the Gulf of Mexico. Generating and disposal facilities would be located on land; this would require a pipeline from the production facilities to the land based operations.

See Phase I (Gustavson and McGraw, 1977) of this report for further details regarding these options.

GEOTHERMAL EXPLOITATION ACTIVITIES LIKELY TO CAUSE ALTERATION OR DESTRUCTION OF HABITATS

Many different activities associated with exploitation of geopressured-geothermal resources can potentially alter or destroy habitats. These include the construction and maintenance of industrial facilities, waste management activities, secondary energy use facilities, land subsidence (unintentional) and several possible unusual hazards.

Construction and maintenance of facilities

A geothermal electric production field has many characteristics similar to those of other heavy industrial sites. Facilities which may be constructed and maintained in a field include a power plant, wells (both for extraction of the resource and injection of the waste effluent), cooling ponds or towers, pipelines, powerlines, canals, channelized stream beds, dams and impoundments, and roads. All of these structures replace whatever habitat existed prior to their construction.

The power plant site would require a minimum of 10 acres (Phase I: Gustavson and McGraw, 1977). The site would house conversion systems (including: heat exchange equipment, turbines, and electrical generators), cooling devices, and electrical switching yards. An entire land-based field is expected to occupy approximately 10 square miles (Phase I). It will include production and injection wells, pipelines, roads and holding ponds outside the 10 acre power plant locale. The extent of pipelines would vary depending on the location scenario.

General habitat destruction is likely to occur during construction and maintenance operations. Some areas will be markedly altered (either previously agricultural or natural biological communities). Sizes of areas affected and durations of such effects would vary during drilling phases and other stages of operations (see U.S. Fish and Wildlife Service, 1976). Any activities which modify the hydrological, thermal or physiographic structure of environments can cause alteration of vegetation.

Physical changes which can destroy vegetation can also produce sub-lethal stresses. These may alter the characteristics of a particular species without completely eliminating it. They include physiological effects on rates of biological processes, genetic diversity within populations, population size and productivity. Any change which increases or decreases the range of variation of a physical or chemical environmental variable can produce biological changes. This is true of both natural species of vegetation and agricultural crops. For example aquatic plants would probably exhibit increases in rates of physiological processes during periods of thermal pollution, if other factors did not inhibit such processes; and the areal extent of certain types of vegetational ground cover could be affected by the amount of flooding related to various activities.

During the construction phase, alteration of the biophysical system would result from clearance of vegetation, grading, cut and fill, soil compaction, impervious surfacing and emplacement of structures. The most prominent impacts from vegetation and soil disturbance are short and long-term changes in plant cover, other habitat changes, and accelerated erosion and changes in soil temperature and moisture (U.S. Fish and Wildlife Service, 1976).

Physiographic changes induced by construction activities may permanently decrease the area's ability to support natural or agricultural vegetation. Natural revegetation occurs as successional changes with marked effects on wildlife because of changes in plant abundance and species diversity. Because a power plant must be located in a geothermal field (large energy losses would result from distant transport of geothermal fluids) there may be few options to avoid specific types of habitats. Agricultural or natural vegetation could be directly lost. Indirect losses could result from drainage alterations caused by deliberate earth movements or unintentional land subsidence (to be discussed in a later section).

The following account from Fraser (unpublished) illustrates the importance of planning for details of local habitats. This was written primarily in reference to the Geysers geothermal area in northern California, but the principles illustrated are of general relevance in assessment of importance of impacts on the biosphere:

> "We realize that this entire area will not be developed. There will be substantial patches of land between the areas devegetated by roads, pipelines, power plants and other facilities. The undisturbed lands will continue to support wildlife, and it could be argued that since only 30 to 50 percent of the land surface within a developed area may be lost to wildlife, the populations are reduced only 30 to 50 percent. However, this argument does not consider some other factors such as "critical" habitat types and the tolerance of some species to human disturbance. Critical habitat types do not cover large areas, but they are necessary to the survival of many species which may occupy quite broad ranges. Examples of critical habitat types are snags and large trees used by birds for roosting and nesting; springs and streams which serve as watering holes; meadows and glades needed by deer for fawning, and streamside vegetation. If an eagle nesting tree or deer fawning ground on a 1000 acre plot is eliminated by development, these animals could disappear from the entire area. Streamside vegetation is critical for the existence of many birds and mammals that may range over considerable distances. Its losses could result in their elimination over the entire area of their adjacent range. Destruction of springs or streams by development would have similar consequences."

Edge effects created by vegetation clearance may aid some species but reduce or eliminate others. Habitats lost by construction of roads, well pads, and power plants may include breeding and wintering areas for shorebirds, wading birds, rails or other waterfowl (Shinn, 1976). Terrestrial animals may lose habitats in which they feed, migrate, and reproduce. Habitats in offshore locations (scenario 3) could be temporarily lost, but there are indications that offshore structures such as drilling rigs, may result in increased marine habitat diversity because they function as "artificial reefs". Bottom irregularities created by drilling rigs and permanent platforms could disrupt local water circulation patterns. Alterations in nutrient cycles may result in changes in the rate of energy flow through an ecosystem and in the relationships among species.

Soil erosion is a serious long-term impact. Construction sites have a higher potential for sediment runoff from erosion than any other land activity (Midwest Research Institute, 1973). The magnitude of such erosion is greatly affected by slope. Increased erosion results in water pollution, and reduced stability of water runoff patterns; this may adversely affect salinity and circulation of coastal waters. This is an especially critical problem in estuarine nursery areas. Sediment suspensions may interfere with the ability of fish to utilize oxygen and locate food. Removal of soil layers by erosion exposes deeper soils to aeration and temperature changes that result in nutrient cycle changes which can have dramatic effects on microflora and fauna. Either long or short-term increases in nutrient availability because of alterations of erosional characteristics may lead to species shifts or exclusion of sensitive organisms from marginal habitats. Clark (1974) discussed the problem of erosion prevention at construction sites and indicated that attempts should be made to maintain as much of the natural pattern of surface water flow as possible. Runoff should be directed through vegetated areas to maintain stability of flows and natural removal of pollutants.

In order to mitigate the effects of construction of a geothermal power plant in the Gulf Coast region, the following constraints are suggested (adapted from Clark, 1974):

(1) In coastal watersheds, erosion and sedimentation should be controlled through available technology.

(2) All topography at the site should facilitate the original natural drainage patterns of the area.

(3) Construction of impervious surfaces should be avoided as much as possible.

(4) Maximize the amount of natural vegetation retained to maintain the natural volume and periodicity of runoff.

(5) Vegetational "buffer" strips should be developed between construction areas and any water courses in order to mitigate persistent washoff of pollutants.

(6) Sensitive areas such as barrier islands (Dolan et al., 1973) and estuarine nurseries should be avoided.

Darnell (1976) contains an extensive review of the effects of construction on wetlands and includes an extensive bibliography which may be useful in determining site specific construction problems.

Geothermal wells, both for production and injection, may have effects on habitats during drilling which differ from those occurring later during use. During drilling, heavy equipment must be moved to and operated on the well site. Brine, steam, hydrocarbons or other substances may escape from the well during drilling. Large quantities of these substances may be released if there is a blow out. A dike around the drilling site may prevent the release of brines or other potential pollutants to surrounding areas (Figure 20). Part of the site is normally excavated to form a sump adjacent to the well for the disposal of fluids associated with drilling.

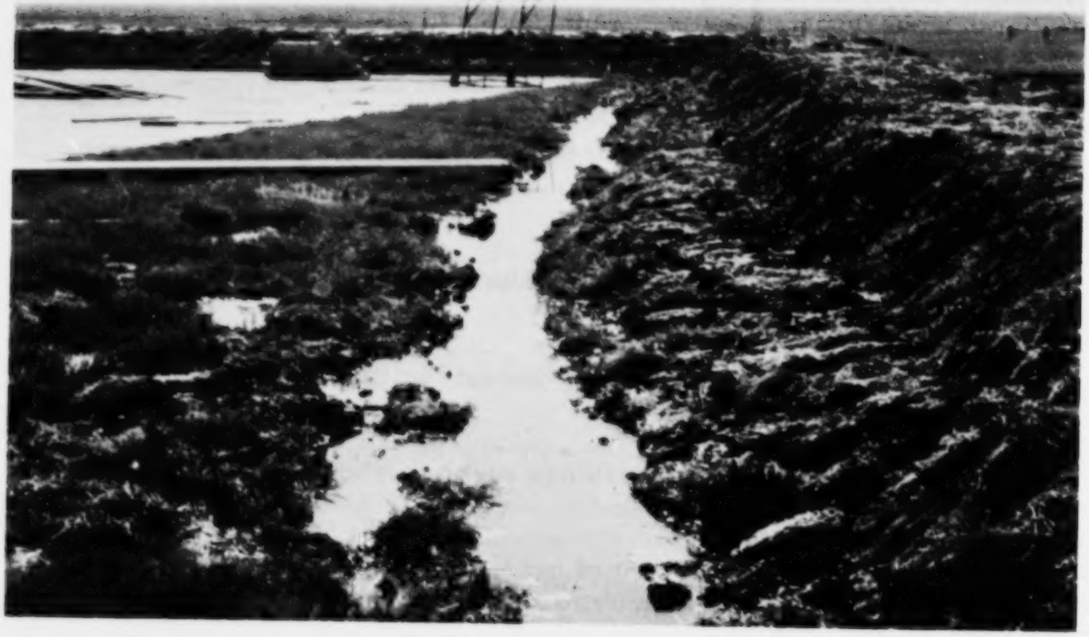


Figure 20. A diked drilling site for a deep oil and gas well in brackish marsh at San Bernard National Wildlife Refuge, Texas, November, 1976. The dike aids containment in case of spills or blowouts, and also helps to keep marsh water out of the drilling site. The drilling platform consists of three layers of boards with each level laid at right angles to the next. A trough surrounds the site on the inside of the dike. Water which accumulates here --principally by seepage from the surrounding marsh--is pumped out to keep the drilling area relatively dry. Photograph by W. L. Longley, Research and Planning Consultants, Inc., Austin, Texas. See also Figure 27.

The extent of land surface occupied and affected by normal drilling operations, without blowouts, is reduced if several wells are directionally drilled from a single pad rather than single wells drilled from single sites. The structure of drilling mud sumps is similar to that which would probably be used for spill-holding ponds, and these will be discussed below under waste management. Drilling mud sumps should be lined with impervious materials, and they are usually covered over with soil after drilling operations are completed. An alternative method of managing drilling fluids is to use large portable steel tanks. The fluids may then be either processed for reuse or disposed of at another site.

It is not known whether it would be necessary to maintain brine flow in a geopressured well in order to prevent fouling. If such flow must be maintained, then disposal facilities must available at the time of completion of the production well.

Cooling systems

Condenser cooling for a geopressured power plant might be accomplished by several methods. These include once-through systems (running stream), dry (air cooled) or wet mechanical draft towers, non-draft evaporative towers or spray ponding (Phase I: Gustavson and McGraw, 1977). All except once-through systems include recirculating fluids. Effects of such facilities on ecosystems may result from release of chemical effluents, demands on local water supplies, release of heat, construction of canals, pipelines or the cooling structures or release of water vapor (Shinn, 1976). Toxic chemicals in effluents may be biocides, corrosion inhibitors, or hydrogen sulfide abatement substances added to the water as part of industrial treatment; corrosion products resulting from reaction of fluids with cooling system machinery; or substances present in geothermal fluids (if these are used as a source of water for the cooling system). (Hanck and Nekoksa, 1975). Water supplies for such systems might be surface (natural streams or lakes or artificial impoundments), ground, sea or geothermal waters. Toxic effluents can enter surrounding environments either as aerosol drift from cooling towers or spray ponds or as liquid discharges if they are not disposed of by deep well injection.

Large withdrawals of fresh, brackish or sea water from natural sources for use in cooling structures could interfere with habitat requirements such as patterns of flow, water depth or temperature, and might result in increased salinities in down drainage water resource areas (Copeland, 1974). Conflicts may arise with agricultural, industrial or residential water budget components of the region (Layton, 1976). This applies particularly to the lower Texas coast. For drought periods, many Texas rivers are already over-allocated for various withdrawals

(General Land Office of Texas, 1976; Hubbs, 1973).

All cooling systems add heat to the local atmospheric or aquatic environment (see section describing thermal discharge, p. 166). Facilities for cooling replace or modify previous habitats. All the systems discussed except air cooled towers add water vapor to the atmosphere.

Once-through cooling systems do not produce greatly concentrated effluents, and they usually do not greatly raise the temperature of the cooling water. They require relatively larger volumes of water, but they result in less evaporation than other systems. Canals are often used for water transport. These can affect drainage patterns, especially in marshes (Clark, 1974). Aquatic organisms may become entrained in the system, and populations and communities may be affected near discharge areas (Boyer and Wiedersum, 1973; Clark, 1974; Eraslan, 1976; Eraslan _et al._, 1976; Gibbons and Sharitz, 1974; Holland _et al._, 1971; Strawn _et al._, 1972-1975; Thorhaug, 1976). Once-through systems do not require large land areas for ponds or reservoirs if large natural water bodies are accessible.

Dry air-cooled mechanical draft towers utilize contained fluids and do not release liquid or aerosol chemicals to the environment. They do not require a continuous water source. Heat is discharged entirely to the atmosphere, and this may dessicate local environments. Few pipelines are required--only those to connect with the condenser system. Less land area is required than for once-through or ponding systems. Air-cooled towers would be unable to meet entire cooling requirements during summer in the Gulf Coast climate (Muehlberg and Shepherd,1975).

Wet mechanical draft towers, non-draft evaporative towers, and spray ponds all may release toxic substances to surrounding areas either as aerosol drift or as discharges of concentrated "blow down" water. Because these systems depend on evaporation for heat flux, they require large volumes of water. Canals are not usually required for evaporative towers, but pipelines are necessary both for connections to the condenser system and for disposal of blowdown water. Land area requirements of evaporative towers are similar to those for dry towers, but they may also require holding ponds for temporary blowdown water disposal. There may also be a solid waste disposal problem for towers using hydrogen sulfide abatement precipitation methods (Hanck and Nekoksa, 1975). Ponding systems require much larger land surface areas than other cooling methods, and they may utilize small canals. Ponds and canals may interfere with local natural drainage patterns. They may also be subject to overflow during heavy rains.

Table 8 summarizes the waste streams from a geopressured system proposed for Willacy County. It should be noted that the model upon which these figures are based assumes concentrations of substances in the source brine which are probably lower than those which will be encountered in geopressured fluids based on current knowledge (see Phase I). The summary of waste streams includes data on potential cooling tower pollutants.

The Willacy model would use water wells and condensation from the power plant system as water for the cooling tower. Corrosion and fouling inhibitors added to the cooling water would include sodium chromate, sodium polysilicate, and sodium pentachlorophenate. Quantities and details of these are contained in Muehlberg and Shepherd (1975). A summary of the operations of the proposed single stage flash electrical generating, methane recovering, and condensed water producing system for the Willacy site is included in Figure 21. In this system cooling tower blowdown would be discharged to a holding pond.

Figure 22 shows a wet mechanical draft cooling tower at the Geysers field which utilizes water condensed from the geothermal steam. The water contains hydrogen sulfide, boron, ammonia, mercury and various additives (Hanck and Nekoksa, 1975; Andersen and Wallace, 1976). In addition to the relatively small amount of land which is occupied by the cooling tower, the surrounding area is affected by aerosol droplets. An attempt has been made to revegetate the surrounding area with native species of plants, but this has not been successful in the part of the area which appears to be receiving the greatest rate of aerosol deposition. Blowdown water at the Geysers is disposed of by injection into the geothermal reservoir.

The following differences should be noted between the cooling scenario of the Geysers and those of geopressured-geothermal systems. Blowdown water from geopressured cooling systems probably could not be economically injected into the geothermal reservoir. However, injection into shallower formations would probably be feasible. Mercury, a substantial component of waters from the Geysers is not expected to be a significant component of geopressured waters, although currently there are no analyses for it. Hydrogen sulfide may be absent from geopressured fluids or at lower concentrations than in fluids from the Geyser's area (Kharaka et al., 1977a, b; Gustavson and Kreitler, 1976).

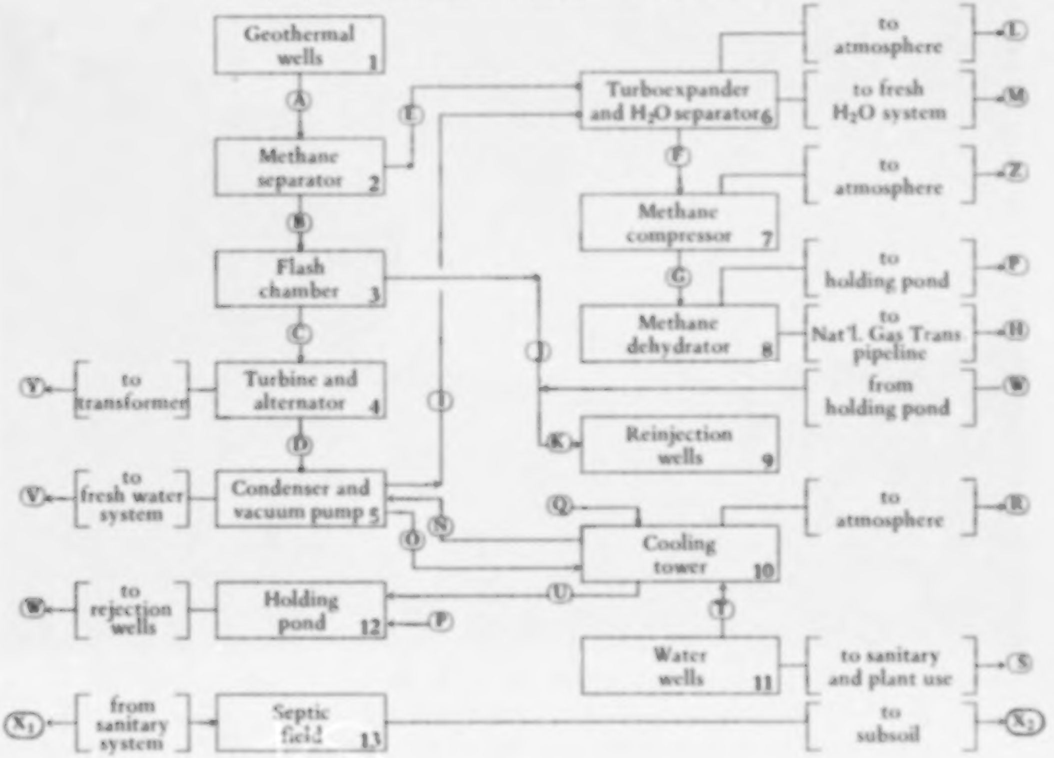
Brungs (1976) contains extensive information on the effects of chlorinated cooling water on aquatic life (see also Dickson et al., 1974; Lauer et al., 1975 and other references in the bibliographies of this report).

Table 8. Summary of waste streams from a geopressured-geothermal energy system proposed for a site in Willacy County, Texas.*

Identity of streams (*see* Figure II)	Physical state of waste stream	Composition	Discharged to	Quantity
†Cooling tower exhaust	Gas: 105°F	Normal air saturated with H_2O: carries liquid brine droplets containing CrO_4	Atmosphere: 40 ft above grade	2.98×10^5 lb/min dry air
Cooling tower blowdown	Liquid: 85°F	Brine containing ~20,000 ppm TDS including 10 ppm CrO_4 and Na pentachlorophenate	Holding pond	81 gpm
Dehydrator exhaust	Liquid: 212°F	H_2O containing ~40 ppm triethylene glycol	Holding pond	~4 gpm
Holding pond effluent	Liquid: ~80°F ~45 psia	Similar to cooling tower blowdown	Reinjection wells	~62 gpm
Reinjection stream	Liquid: 240°F 300 psi	Brine ~12,000 ppm TDS	Sand stratum ~6,500 ft below surface	~6,500 gpm
†Air cooler exhaust	Gas: 20°F above ambient	Normal air	Atmosphere: 20-50 ft above grade	1.1×10^6 scfm
†Air cooler exhaust	Gas: 20°F above ambient	Normal air	Atmosphere: 20-50 ft above grade	6×10^5 scfm
†Septic field percolation	Liquid: ambient	Water: contains soluble N and organics	Soil: 2-3 ft below grade	~4 gpm

*From Muehlberg and Shepherd, 1975.
†Ultimate waste stream leaving installation.

Figure 21. Unit operations of a geopressured-geothermal energy system proposed for a site in Willacy County, Texas.*


Geothermal wells 1
Methane separator 2
Flash chamber 3
Turbine and alternator 4
Condenser and vacuum pump 5
Turboexpander and H2O separator 6
Methane compressor 7
Methane dehydrator 8
Reinjection wells 9
Cooling tower 10
Water wells 11
Holding pond 12
Septic field 13
to atmosphere
to fresh H2O system
to atmosphere
to holding pond
to Nat'l. Gas Trans pipeline
from holding pond
to atmosphere
to sanitary and plant use
to subsoil
to transformer
to fresh water system
to rejection wells
from sanitary system
A
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X1
X2

*From Muehlberg and Shepherd (1975).

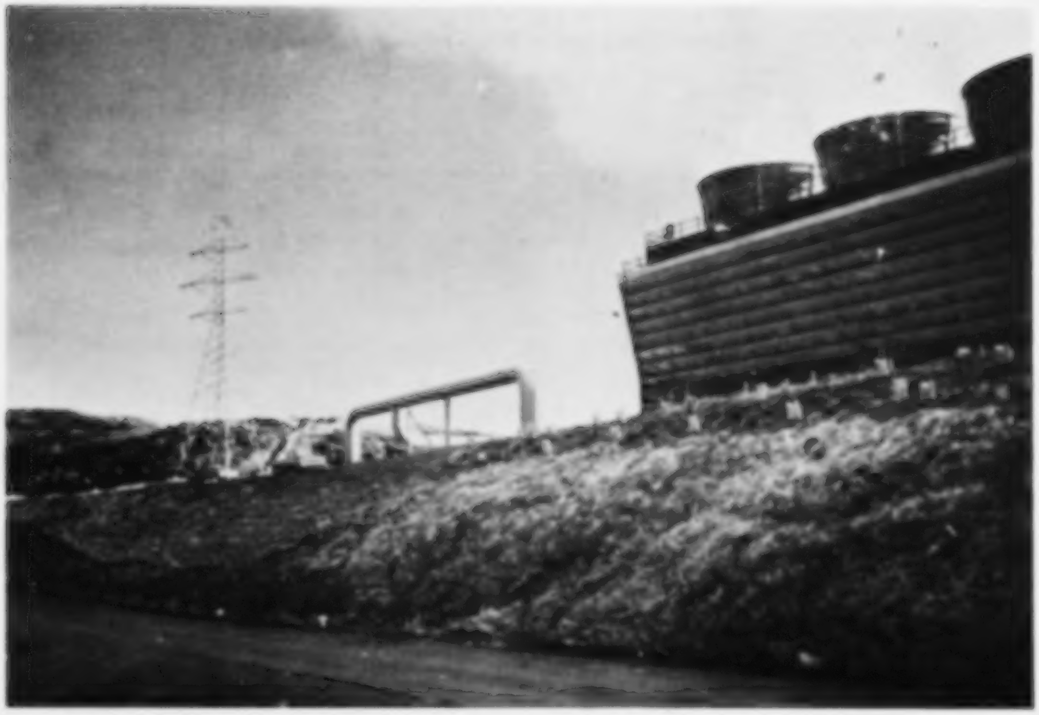

Figure 22. Wet mechnical draft cooling tower, steam pipeline, powerline, and a partially revegetated slope. Geysers geothermal steam field, California, January, 1977. Photograph by M. Tandy.

Spill holding ponds

Even though deep well injection of spent geopressured fluid wastes may be feasible, it appears that it would be necessary to construct holding ponds capable of retaining up to 5,000 m^3 (30,000 bbl)/day to mitigate effects of an uncontrolled flow which might result from a blowout or breakdown of the pipeline or injection system. The amount of time that might be required for a shutdown of the geopressured fluid flow during a system failure or a large-scale uncontrolled spill is not known. Temporary holding ponds capable of retaining as much as 2-3 days of geothermal fluid flow might be necessary. Estimates of pond size requirements indicate that a 4-acre-foot holding capacity may be sufficient for this purpose. Such ponds would preclude other uses of their land surface area and would involve construction hazards as mentioned in previous sections.

Figure 23 shows a state-of-the-art brine holding pond at the ERDA experimental geothermal facility at Niland in California's Imperial Valley. At the time, the binary conversion facility was shut down because of technical problems. The brine was entering the pond because not all of the flow from the production wells could be handled by the disposal wells.

Environmental impacts which may be associated with retaining large quantities of highly saline geothermal brines include releases of brine components to the atmosphere, escape of fluids from holding ponds because of permeability of pond linings (Turk, 1974) or unusual circumstances such as storms, which could result in overflow of the impounded fluids. Temperatures of the spent fluids may be as high as 71°C (160°F) (Phase I: Gustavson and McGraw, 1977). Pond containment of large quantities of heated water might result in local climatic alterations, changes in terrestrial organisms and possible marked effects on aquatic species if the fluids should escape to natural water systems.

Evaporation from holding ponds might add considerable amounts of heat and water vapor to the local atmosphere as well as quantities of salts of methane, non-methane hydrocarbons, hydrogen sulfide, boric acid, and ammonia (Kharaka _et al._, 1977a, b). Some of these components could have significant negative impacts in marshlands and estuarine systems of the coastal zone. In the immediate vicinity of the generating facility, degradation of vegetation and increases in soil salinity might result. These effects might be short or long-term depending upon the frequency and duration of deposition and climatic factors.

Release of spent geothermal fluids from holding ponds to natural bodies of water could present severe environmental problems. Contamination of ground water, freshwater streams, and estuarine nursery areas can result in the elimination of aquatic flora and fauna intolerant of rapid

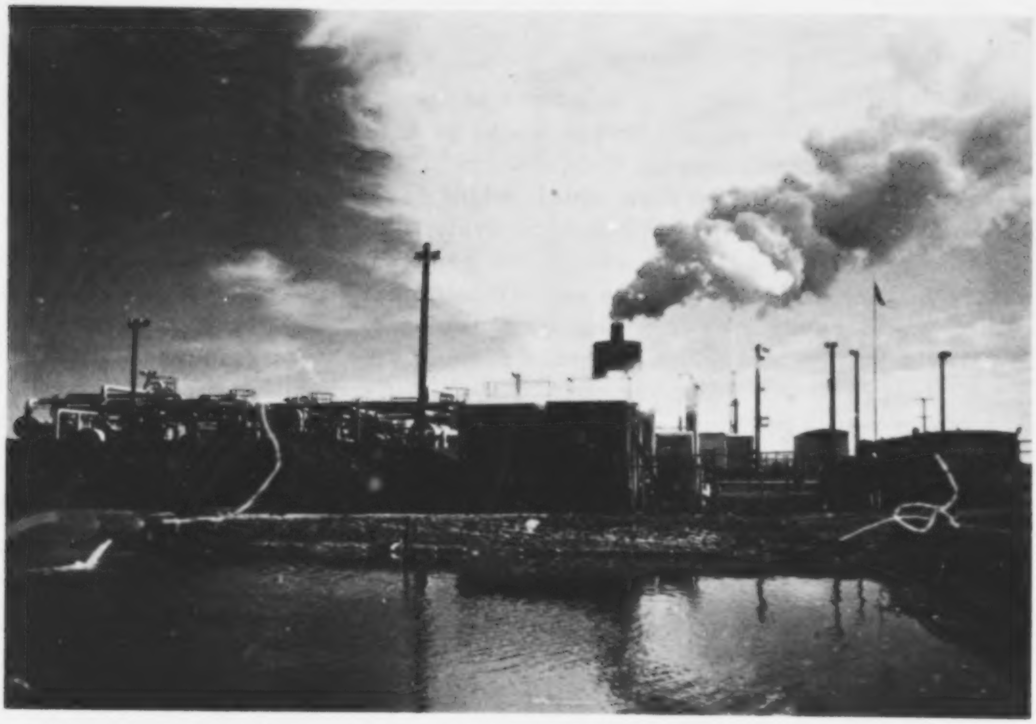

Figure 23. Brine holding pond, generating plant, and other experimental equipment at the ERDA experimental facility, Niland, Imperial Valley, California, January 1977. This earthen pond is receiving brines from three fluid jets at the left. Photograph by M. Tandy.

salinity and temperature fluctuations. All of the above problems are considered in greater detail in the waste disposal section of this report.

Pipelines

Systems of pipelines to collect and carry geothermal fluids from production wells to the power plant site and later to the disposal facilities are necessary. In addition, pipelines would also be associated with any alternate industrial uses such as sulfur processing, gas refining, mariculture or pulp and paper industries. Details of the latter are beyond the scope of our task, although they must be eventually considered in addressing the impacts of a particular facility (Clark, 1974). Pipelines may be buried or elevated. In the Gulf Coast region, long distance oil and gas pipelines are usually buried (Phase I: Gustavson and McGraw, 1977).

Methods of laying buried pipelines have been described in detail by McGinnis et al. (1972) and the techniques pertinent to the current study are discussed in Phase I of this report (Gustavson and McGraw, 1977). They describe excavation methods used in land areas and two techniques used in wetlands: (1) "push-shove" and (2) flotation methods. Of the latter two, the "push-shove" technique results in the least amount of disturbance to marshland and its biota, and negative impacts may be minimized by back filling and restoration. Area lost in the "push-shove" method has been estimated to be 0.25 hectare/km (6 acres/mile) of line (Conner et al., 1976).

Effects of burying pipelines on land include disturbance of soil and vegetation along the route. Some types of vegetation, particularly prairie grasses and forbs, can often become reestablished along a corridor within a few months (Figure 24). Forest communities may require centuries for restoration by natural ecological succession (Odum, 1959, 1971). The importance of these effects will vary according to a particular site.

Little is known about the effects of pipeline construction on animal behavior. Pipelines crossing habitats of protected species require special attention relative to loss of habitat, dissection of populations or disturbance of reproductive behavior. Pipeline construction can be either beneficial or detrimental to deer. A 15-meter pipeline corridor through heavily canopied forest land would usually result in a good growth of forbs and browse because of increased ground exposure to sunlight. However, a pipeline through good deer habitat usually results in elimination of browse and reduction of available habitat (Blevins and Novak, 1975). It is not known whether high temperatures of brine transporting lines would affect vegetation; this might occur even if lines

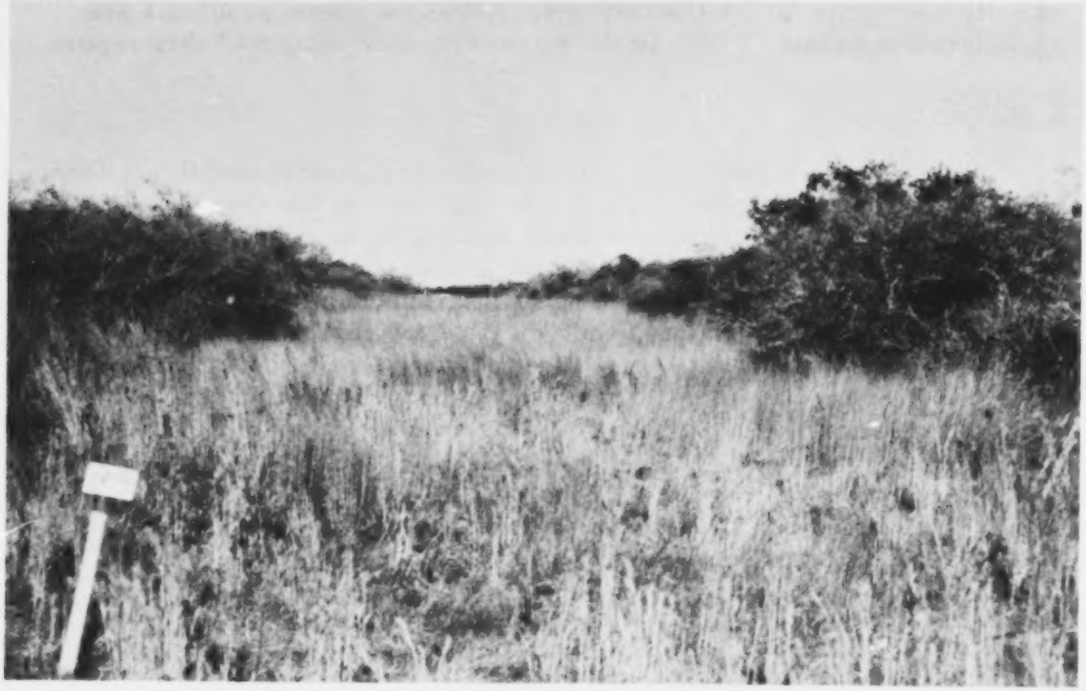

Figure 24. A pipeline corridor for a 31 cm. (12 in.) diameter gas line through coastal brush land. A prairie sere (temporary biological community, which is a stage of ecological successional processes that would normally return the area to brushland) is maintained by continual clearing and mowing of the corridor. This is required by the U.S. Fish and Wildlife Service to facilitate checks for leaks. It may also improve the area as deer habitat. Aransas National Wildlife Refuge, Texas, March, 1977. Photograph by W. L. Longley, R.P.C., Inc., Austin, Texas.

were insulated to reduce heat loss. Right-of-way for land-based pipelines is usually 38 meters wide (Stone, 1975).

Figure 25 shows steam pipelines in the Geysers geothermal field. Note that the expansion loops are constructed vertically. This means that a smaller area of land surface needs to be disturbed to provide for the pipeline right of way. This is especially important in the Geysers area because removal of surface vegetation increases the likelihood of destabilization of soils and landslides. Landslides are not a problem in the low-lying Gulf coast area, but marshlands and other areas are biologically highly productive, and engineering techniques such as these which reduce the size of the area damaged should be strongly considered when they are feasible.

In aquatic habitats (wetlands, bays, estuaries and the Gulf) there may be significant local environmental impacts from pipeline construction (McGinnis et al., 1972). Major effects result from loss of habitat and vegetation in areas occupied by spoil banks, levees, and the pipeline channel. Stone (1975) has estimated the right-of-way for marsh area pipelines to about 46 meters wide. Reduction of water quality would probably result from the redistribution of heavy metals, pesticides, sulfides and particulate matter contained in dredged spoil. Canals and levees often interrupt natural drainage of marsh areas and can locally raise or lower water levels. Major concerns are the release of nutrients; oxidation of sulfides to sulfuric acid, with resultant pH changes and possible dissolution of heavy metals; and increases in turbidity levels and oxygen demand. When canals are cut through marsh lands, increases in saltwater influx may result. Open ditches provide a more direct unimpeded avenue of exchange of tidal water and may allow a salt wedge to protrude farther inland along stream systems; this may expose stenohaline species to abnormal salinity fluctuations (Figure 26). Biological productivity loss in marshes may be 5 to 10 times that lost in agricultural lands on an equal area basis. Ditching without backfilling results in effectively permanent loss of vegetation and productivity when wetlands are converted to a continually submerged area (McGinnis et al., 1972). Vital areas and areas of environmental concern such as barrier islands, oyster reefs, shellfish beds, grass beds and inlets (Clark, 1974) should be avoided in planning pipeline routes.

Connor et al. (1976) presented guidelines for mitigation of pipe laying in wetland areas, and the following is adapted from their discussion:

(1) Use natural corridors and levees for new pipelines.

(2) Existing pipeline ditches should be used for new pipelines wherever possible.

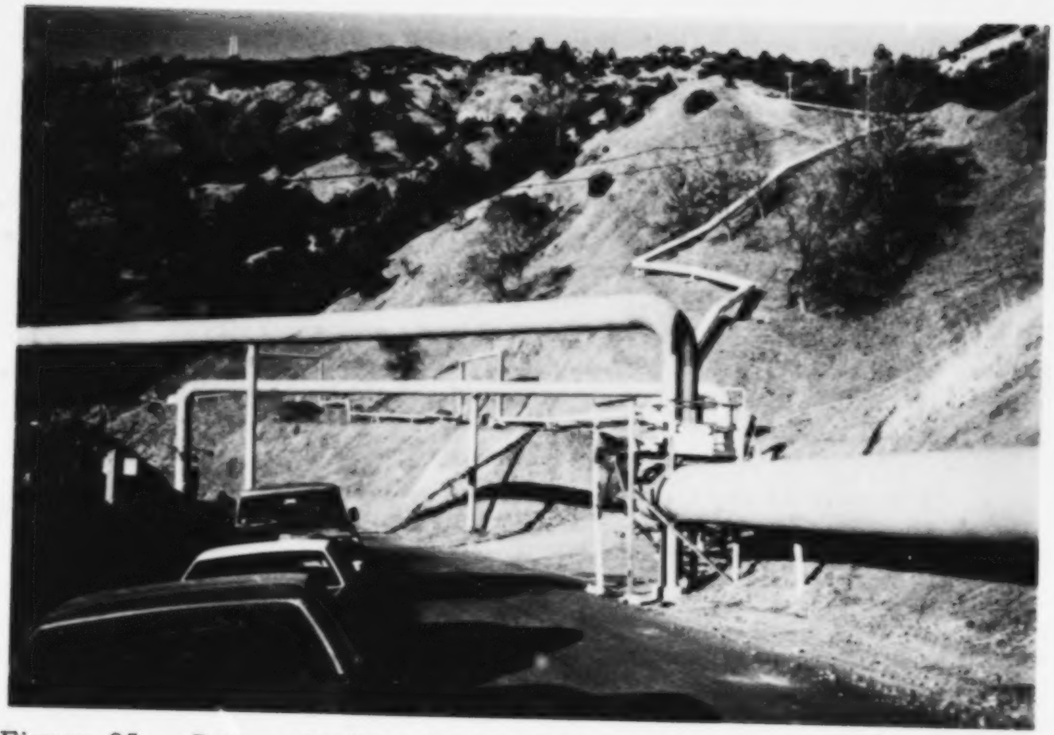

Figure 25. Steam pipelines in the Geysers geothermal field, California, January, 1977. The large U-shaped bend in the pipeline is an expansion joint to reduce the likelihood of ruptures either because of thermal expansion or contraction, or displacement associated with earthquakes. Pipelines in the Gulf Coast are likely to be buried. Photograph by Tandy.

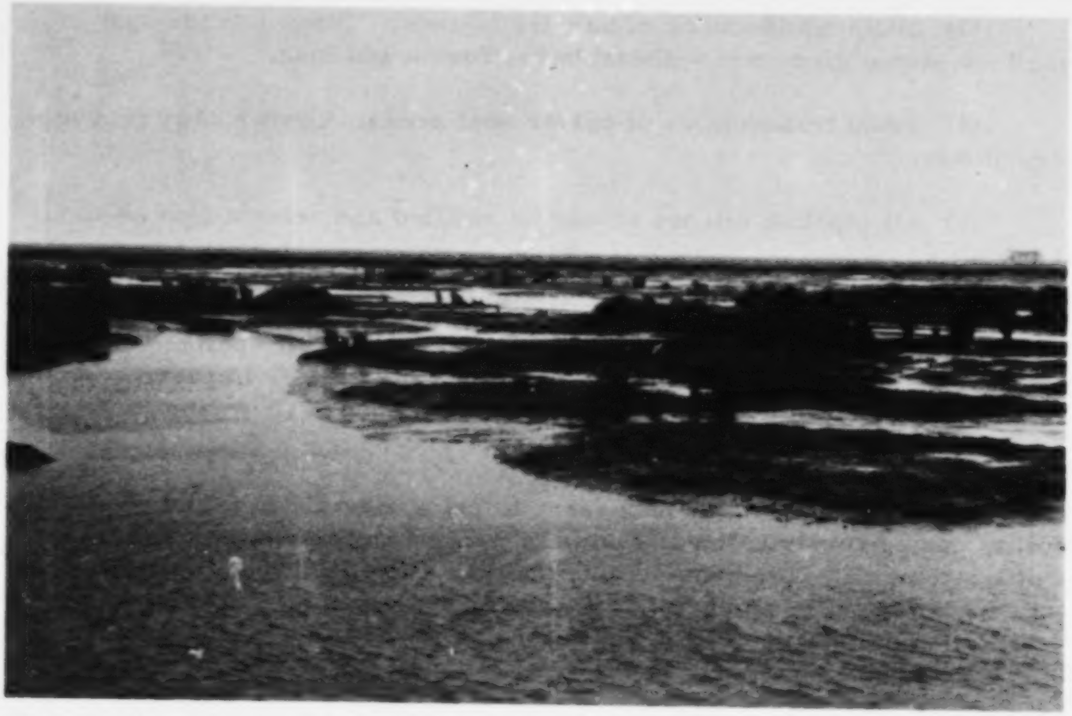

Figure 26. A formerly freshwater marsh which is becoming a brackish marsh because of salinity changes associated with pipeline construction. The low vegetation is principally Eleochaeris sp. which is characteristic of freshwater marsh. The emergent grasses are principally Spartina patens which is a brackish marsh species. A pipeline was laid through the marsh to the right of the photograph, and the ditch was not filled. This currently provides a water circulation connection between the marsh and Lake Calcasieu which is now brackish. Saline National Wildlife Refuge, Texas, March, 1977. Photograph by W. L. Longley, R. P. C., Inc., Austin, Texas.

(3) Avoid transections of barrier islands. These islands are fragile systems which are vulnerable to erosion and loss.

(4) Avoid transections of oyster reef areas. Oyster beds recover very slowly.

(5) All pipeline ditches should be refilled and refurbished as soon as possible.

McGinnis et al. (1972) point out that many of the environmental effects associated with the construction and operation of pipeline services are unavoidable, but proper planning can minimize major impacts.

Powerlines and powerline corridors

Powerlines would be necessary to bring electricity to the proposed facility during construction and later to carry generated power to areas of utilization. Environmental problems may arise both from powerlines and supporting towers and from clearing and maintaining corridors along rights-of-way. These effects would not be confined to the geothermal field. Problems associated with clearing of natural vegetation have been discussed in previous sections.

Major concerns with lines and towers are their potential effects on birds. Large wading birds, which are not particularly good fliers, especially in adverse wind conditions, tend to collide with powerlines. In addition, powerlines cause birds to alter their normal flight patterns; this may expose them to other hazards or make previously desirable habitats undesirable (Hunt, 1973). Electromagnetic effects may disturb bird orientation near the lines (Bridges, 1975). Collisions and alterations of flight patterns are probably the most important concerns (Shinn, 1976). Migratory waterfowl may be particularly affected because large numbers of these birds pass through or winter in the Texas-Louisiana Coastal zone. See the biological resource section of this report.

Two basic and rather simple mitigations apply to powerline impacts. First, major areas of bird movement at or near any site proposed for geothermal exploitation should be identified and avoided. This might be critical for endangered or other important species such as the Brown Pelican. Secondly, if lines must be used in critical wildlife areas, burial should be considered.

Canals and channels

Canals and channels other than those used for pipelines or cooling water may be required. These might be large channels to provide access of heavy equipment to a site (scenarios 2 or 3), smaller canals to carry waste brine effluent, or structures to control runoff. Large channels might be used for rig installation, navigation or pipeline construction. Waterways are often dredged to provide transportation access for installation of heavy equipment in isolated areas of wetlands. Disposal of dredged material from such waterways presents problems in the almost flat terrain. Habitat areas covered by spoil banks are destroyed. A common procedure is to place dredged material on an adjacent bank of the channel; this produces long linear spoil banks or a series of mounds or islands.

Dredging interrupts the energy flow of marshes by changing circulation patterns (Copeland and Dickens, 1974). Copeland (1974) indicated that the dredging of the Intracoastal Canal in Texas and its associated spoil bank prevents water from circulating normally over mudflats during tidal fluctuations. Salt layers left on the mudflat surfaces by evaporation have been blown over several thousand acres of pasture land, destroying the grass cover. Channeling results in rapid drainage; this causes nutrients to be removed from wetlands (Copeland and Dickens, 1974) and often allows saltwater penetration into freshwater environments (Eleuterius, 1971; Copeland and Dickens, 1974). During dredging operations, stirring of bottom sediments into suspension greatly increases turbidity levels and may release toxic materials, such as heavy metals, to the environment. Dredging removes shallow marsh grass and weedy bottom environments essential to juveniles of many species utilizing these areas as nursery grounds.

Turbidity is one of the more serious problems associated with dredging, and it continues to be a problem for some time after spoil deposition because sediments are eroded from spoil banks adjacent to canals. Turbidity may result in the impairment of feeding mechanisms in shellfish, especially oysters, and other filter feeders. Bottom dwelling plants and animals are often smothered by deposition of fine sediments on the bottom. Lindall, et al. (1972) indicated that high turbidity levels may impair fish spawning and gill function. Photosynthesis may be decreased during periods of high turbidity, thus reducing productivity.

Of the five types of dredges currently being used (dipper, ladder, bucket, pipeline and hopper), the hydraulic dredges (pipeline and hopper) cause the least disturbance at the dredge site from the release of polluting sediments, but they have a high potential for ecological disturbance at the outlet of the pipeline where the spoil is deposited, particularly if the spoil contains a high proportion of polluting material such as organic matter, toxic substances and fine sediments (Clark, 1974).

Spoil banks produced during dredging operations cause several environmental problems. They may impede normal water flow to varying degrees depending upon the topography of the bank (orientation, height, slope, etc.). In southwestern Louisiana, a canal from Freshwater Bayou to Schooner Bayou was dredged which resulted in a continuous levee throughout its length with spoil as high as twenty feet. Normal tidal circulation in the marsh was thus prevented (Eleuterius, 1971). Because flow to normally tidally flushed areas may be curtailed, plants and animals there can be subjected to higher salinities as evaporation occurs (Teal and Teal, 1969). Construction of the Brownsville Ship Channel across the southern end of the Laguna Madre in Texas resulted in spoil banks blocking the entrance to South Bay, leaving only a shallow entrance for water exchange. Reduction in flushing and circulation in the bay was accompanied by decreased production levels and increased salinity, and the bay began filling with sediments (Breuer, 1962). In freshwater areas, spoil banks may cause flooding of species which normally are only periodically inundated; this may eliminate these organisms. Spoil sediments may contain unusual or toxic materials in high concentrations, and these may be leached out as the spoil bank is eroded.

Although most effects of spoil deposition are ecologically detrimental, there may sometimes be habitat improvements resulting from dredged canals and spoil placements. Channel construction in a shallow bay or brackish marsh frequently benefits the fishery even though some habitat may be destroyed (Chapman, 1968). This may occur because the opening of previously isolated areas may provide access to estuarine organisms; but other organisms that are adapted to the previously lower salinity conditions may be harmed.

Clark (1974) states that removing sediments from fresh or salt water habitats is known to damage populations in the following locales:

(1) In the immediate areas of dredging (by disruption of bottom organisms and their habitats).

(2) In areas of intentional disposal of dredged materials (by covering existing bottom organisms and modifying habitats).

(3) In unexpected areas within the general region where water quality may be altered (increased turbidity, reduction in levels of dissolved oxygen because of suspension of oxygen-demanding sediments, release of toxic materials, etc.) or where bottom organisms are covered by a smothering deposit.

Copeland (1974) stated that "when a part of an estuary is isolated from previous circulation patterns by spoil banks, dredgings, or dams, new ecological systems replace the old ones." Trent et al. (1976) investigated the effects of dredged canals in a housing development and found reductions in the numbers of species present and in total numbers of individual organisms. These reductions were attributed to permanent loss of intertidal vegetation, low abundance of detrital material and benthic macroinvertebrates, and eutrophic conditions in the canal areas. The effects of dredging and spoil deposition can have marked effects on ecosystems of coastal regions, but many of these problems can be mitigated through careful planning and adequate research. Herbich and Schiller (1974) have summarized effects of current state-of-the-art techniques of dredging on the environment.

If canals were used to transport brine effluents to disposal sites, they would have to be constructed to prevent such fluids from entering surrounding environments. In addition to their linings' being impervious, they would need to be structured so that they would not overflow during periods of heavy rainfall. Containment of toxic gases such as hydrogen sulfide, methane or ammonia in open canals would not be possible. Because of these problems, open canals should not be used to transport brines.

Channels might be used to control potential flood runoff during periods of heavy rain. Any structure which is effectively impervious cover prevents rainwater from entering soil. Unless such rainfall is contained in ponds or other structures capable of accommodating its volume, it adds to floodwater runoff. The usual engineering approach to this problem has been to straighten and increase the size of natural stream channels. This aggravates problems farther downstream. Careful and very site specific design features are necessary to deal with such problems effectively.

Roads

The land-based facilities of any geothermal exploitation scenario will require roads. These will be used to transport heavy equipment during drilling and construction phases and for transport of supplies and personnel during production operations (Figure 27). Construction of roads may result in severe impacts on local wetland environments (Phase I: Gustavson and McGraw, 1977).

Roads replace habitats along rights-of-way, surfaced ones are impervious structures that can contribute to increased rainwater runoff, and they may alter drainage patterns. Indirect habitat losses may result from their facilitating new forms of land use along road corridors. Major waterflow in coastal areas is often more or less perpendicular to the coast line. Roadways built parallel to the coast can become a serious problem if they are constructed on solid fill causeways that become dams which

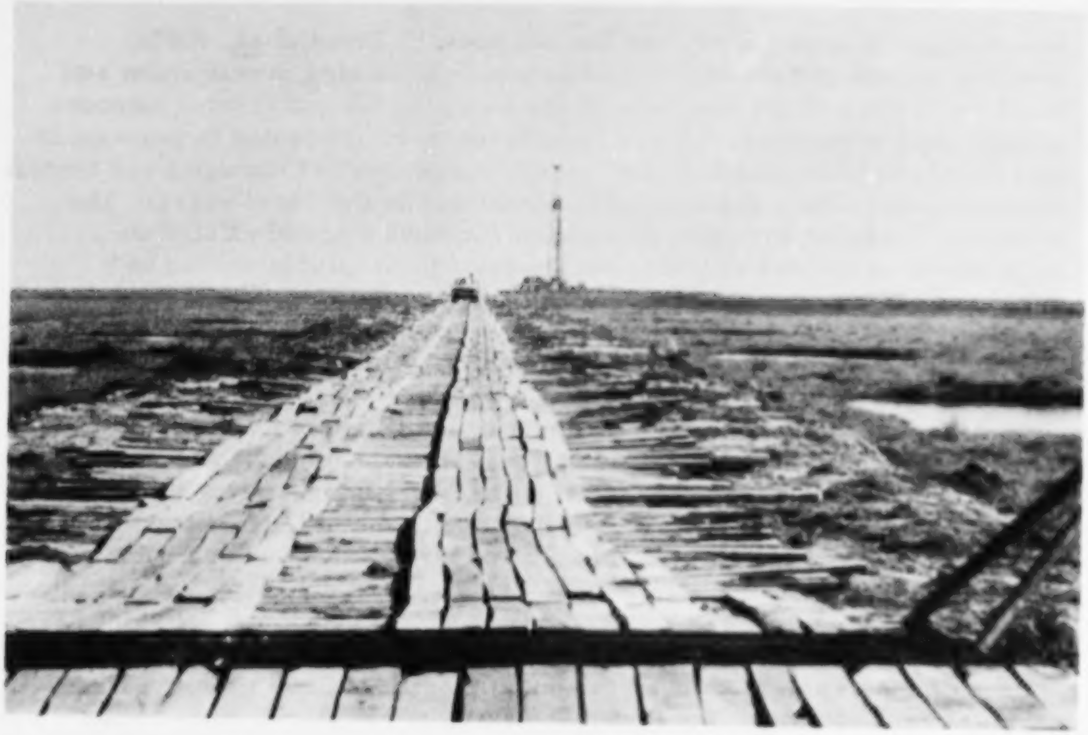

Figure 27. A plank road built on a 1.2 m (4 ft) high levee through brackish marsh to provide access to an oil and gas drilling site. The drilling rig is 2 km (1.25 mi) away in the background. This road is 4.5 km (2.8 mi) long. Boards are laid as described for Figure 20. The 5 m (15 ft) deep pools at intervals at each site of the road are "borrow pits" which were used as sources of fill for the levee. After the site is no longer in use, the marsh can be restored by replacing most of the levee material in the borrow pits. San Bernard National Wildlife Refuge, Texas, November, 1976. Photograph by W. L. Longley, R.P.C., Inc., Austin, Texas.

block natural waterflow and degrade wetlands (Clark, 1974). Other problems associated with road construction include erosion and sedimentation, alteration of stream flow and salinity levels downstream, and increased pollution and eutrophication of coastal waters. Nelson and Godfrey (1974) addressed the problem of road noise in the rural environment.

Clark (1974) made several suggestions to mitigate the impacts of road construction in wetlands:

(1) Major roadways should be located above the coastal flood plain.

(2) Roadways built in coastal watersheds should be designed and located to prevent-runoff of polluted water or interference with natural drainage patterns.

(3) Major roads within the coastal flood plain should be located parallel to land drainage (usually perpendicular to the coast line).

(4) Minor roads should be designed to facilitate the flow of land drainage and coastal waters.

(5) Wetland, tideland and estuarine crossings should be built as elevated structures.

Evaluation of overall impacts of roads associated with geopressured facilities must include consideration of roads servicing secondary industries and related urban areas.

WASTE DISPOSAL PROBLEMS

Geothermal brines

The chemical composition of geopressured-geothermal brines is not completely known. Analyses of fluids from geopressured sediments are now in progress by the U.S. Geological Survey, Menlo Park, California (Kharaka, personal communication) and the Bureau of Economic Geology, University of Texas at Austin. A general knowledge of the concentrations and distributions of major ions is available (see Phase I, Figure 9; Gustavson and McGraw, 1977). It should be noted that these concentrations and distributions will probably vary from site to site, and possibly from well to well, along the Gulf Coast. One would expect some major differences between the chemical compositions of geopressured waters and those of other geothermal areas because of differences in geochemistry of parent rocks. Indications of such variations in brine composition may be perceived by comparing the geothermal brines from wells in other areas (Table 9) with those from formation waters along the Texas coast (Table 10).

Table 9. Chemical composition (expressed in ppm) of selected non-geopressured geothermal fluids from localities other than the Gulf Coast.*

	Castle Rock Springs, Lake County, California *Condensate*	Castle Rock Springs, Lake County, California *Reservoir fluids*	Sulfur Bank Mine, Lake County, California *Hot springs*	Long Valley, Mono County, California	Wairakei, New Zealand	Broadlands, New Zealand	Cerro Prieto, Mexico	Salton Sea, Imperial Valley, California
Li			4.4	2.8	12	12	24.4	215
Na	nd	117.0	1190	390	1235	1050	8238	50,400
K	nd	86.0	23	45	197	224	2058	17,500
Rb				0.48				137
Cs				0.6				16
Mg	0.03	37.0	55	0.1				54
Ca	0.05	10.0	20	0.9			556	28,000
Sr			2.2	0.14				609
Ba				nd				235
Mn			0.1	<0.02				1560
Fe	0.2		0.0	0.05				2090
Cu				<0.03				8
Ag				<0.04				0.8
Zn				0.10				790
Hg		0.054		10^{-4}				0.00
Al	?	<0.02	0.6					
Tl								1.5
Sn								0.5
Pb				<0.1				84
As	nd		0.00	2.2		8		12
Sb				0.2				0.4
F	0.09	8.0	1.0	12	9	7.3		15
Cl	10.2	10.0	644	280	2180	1743	16,329	155,000
Br			1.6	1.1		5.7		120
I			3.2	0.4		0.8		18
B	0.28	24.1	620	15	30	49	17.3	390
Total CO_2	48.9	8.8	2370	346	8 (44)	128 (748)		>108
Total SiO_2	17.9	400.0	42	340	620	805	1291	400
NH_3	25.6	43.1	438	0.4		2.1		386
NO_2			0.00	<0.05				
NO_3^-	5.4	2.2	0	<0.05				
PO_4				0.18				
Totals as H_2S	*61*		12	10	(3.5)	1.0 (120)		17-29
SO_4	7.3	414.0	598	130	34	8		5.4
pH	5.1- 6.7	5.1	6.8	9.2				

*From Weres, Tsao, and Wood (1977).

Table 10. Chemical composition of selected formation waters from the Texas Gulf Coast.*

		Sample Number	
	76GG17	76GG58	76GG63
Well number	Gardiner #1	May Owens #1	Portland #A-3
Field	Chocolate Bayou	East White Point	Portland
County	Brazoria	San Patricio	San Patricio
Production zone	Lower Weiting	Owens	Morris
Perforation interval *m*	3,588-92	3,138-55	3,511-6
Fluid production rates			
Oil and condensate *m^3/day (barrels/day)*	2.1 (13)	3.0 (19)	4.8 (30)
Water *m^3/day (barrels/day)*	48 (301)	1.3 (8)	7.5 (47)
Gas *1,000 m^3/day (1,000 ft^3/day)*	2.7 (96)	14.5 (513)	25 (882)
Temperature			
Measured °C	129	112	126
Quartz °C	128	84	130
Na-K-Ca °C	124	100	120
Original bottom hole pressure *10^6 kn/m^2 (psi)*	172 (7,589)	188 (8,333)	191 (8,455)
Chemical composition *mg/l*			
TDS *calculated total dissolved solids*	68,000	24,900	17,800
Na	24,000	9,250	6,500
K	300	70	68
Rb	0.80	0.30	0.30
NH_3	26	11.0	5.8
Mg	235	31	15
Ca	2,000	200	89
Sr	380	25	7.0
Fe	8.0	70	2.3
Mn	2.7	1.4	0.16
Cl	40,500	14,000	9,270
HCO_3 *field titrated alkalinity*	520	1,200	1,600
SO_4	0.6	22	84
H_2S	0.32	—	—
SiO_2	87	34	93
B	30	24	62
pH	6.3	6.7	6.8

*From Kharaka, Callender, and Wallace (1977).

Except for the data of Kharaka et al. (1977a, b) and Gustavson and Kreitler (1976), we have only one limited analysis of trace elements for geopressured waters. These are included in Table 14, and they are the only analyses that have detected cadmium and lead. The source of these elements is not definitely known to be geothermal fluids. It is possible that the sample bottles were contaminated. The water samples were collected principally for analysis of major ionic constituents and total dissolved solids (Gustavson, personal communication).

The most probable method of disposal of geopressured-geothermal waters is injection into deep permeable geological formations. There is little data available on the capacity of such reservoirs to accept large scale long-term injection of such fluids (Underhill et al., 1976; Gustavson and Kreitler, 1976). Wood (1973) stated that the use of waste-injection wells is a much smaller threat to the environment and to ground water than is the improper surface disposal of such wastes. Problems that may arise as a result of injection procedures include the displacement of brines already present in the formation which may flow to the surface or to fresh aquifers through abandoned test holes or old wells that have been destroyed by corrosion. Also, excessive injection pressure may fracture confining beds and permit geothermal waste fluids to flow into other aquifers (Wood, 1973). These problems have been addressed by Muehlberg and Shepard (1975) in their consideration of a possible geopressured site in Willacy County, Texas. It is probable that substances associated with electrical conversion processing such as corrosion inhibitors, biocides, and corrosion products would be present in the injected fluids which are not present in the receiving reservoirs.

The possible release of brines into surface environments is a major concern. Release of brines could occur from a variety of sources including flooding of canals that might be used to transport waste effluents; leakage or rupture of pipelines; leakage, rupture or overflow of brine holding ponds; leakage or blowouts from production wells; spills associated with various types of failure of the electrical generating system; failure associated with technology used to remove methane from brines; spills associated with injection wells; discharge of cooling water (if geothermal water were used as a coolant); discharge of brines into terrestrial, freshwater, estuarine, or marine systems; or problems associated with the disposal of pipeline scalings.

Even if injection is feasible, the possibility of spills exists. The record of pollution incidents in the Geysers Field in California may give some insight into the nature and frequency of such incidents (see Appendix E). Much larger volumes of liquids would be involved with geopressured operations than are characteristic of the Geysers steam field. Temporary surface disposal may be necessary at various times during normal plant operations or during an injection system shutdown. During these periods, geothermal brines would be retained in holding ponds described earlier.

Potential biological effects of brines

Potential problems associated with storage of the spent fluids in holding ponds include damage to local terrestrial plant life and disruption of animal behavior patterns in the immediate area. Marked effects might result from spills outside holding pond areas (e. g. pipeline ruptures). If brines escaped to freshwater areas, there might be severe salinity problems for organisms intolerant of increased salinity, and toxic compounds may also be present (boron, ammonia, etc.). Downstream drainage areas may be affected, including estuarine and marsh habitats (especially those that contain important nursery grounds for sensitive juvenile stages of organisms). Included in these salinity problems are unusual ionic ratios. Critical aspects of a brine spill are its location and the amount of time required to shut down the system.

The impacts of a geothermal brine spill may include an initial kill of local aquatic life because of osmotic, thermal or other toxic stress, followed by long-term possibly chronic effects of gradual dissipation of elevated levels of salinity, heavy metals and other geothermal compounds. Natural ecological systems which receive such brines are modified in a number of ways which affect water circulation systems, osmotic regulation of aquatic organisms, water stratification, specific heat, hydrogen ion balance, buffer systems, solubility of oxygen, turbidity and ion balance. Such changes result in destruction of bottom communities and soil structure and low species diversity (Moseley and Copeland, 1974). Effects of brine pollution are beginning to be understood from studies of salinas, natural hypersaline lagoons, and brine polluted communities. Very few organisms are capable of adapting to the high salinities, strange chemical balances and varying inputs of brine waters.

Effects of salinity on organisms

Even the most tolerant plant species are able to withstand natural marine salt concentrations of only about 50,000 ppm. Freshwater marsh species have much lower tolerances. Table 11 indicates some of the tolerance ranges of typical plant species found in coastal Texas and Louisiana. The upper limits of salinity that halophytes can tolerate vary with rapidity of the change, duration of change and temperature factors (Waisel, 1972). Many plants either tolerate salinity fluctuations within a given range or have mechanisms available to regulate salt content to some extent. However, the natural distribution of plants in saline environments probably indicates limits of abilities to regulate salt content (Waisel, 1972). Care must be taken to determine the distribution of plants at a

Table 11. Salinity tolerances of some typical plant species found in coastal Texas and Louisiana. Plant salinity ranges from Palmisano (1970) unless noted otherwise.*

Species	Common name	Bay or marsh type where normally found	Salinity (ppm) Low	High	Average
Halodule Wrightii	Shoal-grass	Brackish-Hypersaline	1,000[1]	60,000[1]	—
Ruppia maritima	Widgeon-grass	Brackish-Hypersaline	0[2]	45,000[1]	25,000
Cymodocea filiformis	Manatee-grass	Salt: Brackish	10,000[2]	40,000[2]	—
Thalassia testudinum	Turtle-grass	Salt: Brackish	10,000[2]	50,000[2]	30,000[4]
Halophila Engelmannii	Halophila	Salt: Brackish	23,000[5]	37,000[5]	—
Spartina alterniflora	Cordgrass	Salt	5,500	40,000	16,100
Distichlis spicata	Saltgrass	Salt: Brackish	5,000	50,000	14,200
Juncus Roemerianus	Black Rush	Salt: Brackish	1,000	45,000	—
Scirpus robustus	Salt-marsh Bulrush	Brackish	6,000	39,000	—
Spartina patens	Saltmeadow cordgrass	Intermediate: Brackish	0	39,000	9,600
Scirpus Olneyi	Olney Bulrush	Intermediate: Brackish	5,000	17,000	9,200
Alternanthera philoxeroides	Alligator-weed	Intermediate	0	15,000	1,400
Phragmites communis	Common Reed	Intermediate: Fresh	0	20,500	—
Vigna repens	Wild Cowpea	Intermediate: Fresh	2,000	12,000	—
Sagittaria falcata	Sythefruite Arrowhead	Intermediate: Fresh	0	9,500	2,300
Cladium jamaicense	Jamaica Saw-grass	Fresh	0	3,000	—
Panicum hemitomon	Maidencane	Fresh	0	1,000	900
Eichornia crassipes	Water-hyacinth	Fresh	0	500	—

[1] Simmons (1957) [3] McMillan and Moseley (1967)
[2] McMillan (1974) [4] Zieman (1975)
[5] Approximate averages from various literature

*Names after Correll and Johnston (1970).

particular site and their natural salinity regimes. Low level chronic effects may be very important. Although some plants may be able to survive during periods of salinity stress, they may not be able to grow and reproduce. Hoese (1967) states that the Gulf salt marsh system based on Spartina alterniflora would probably be destroyed by salinities which approached or exceeded 50,000 ppm. In addition, plant species are extremely sensitive to ionic imbalances. Effects of a geopressured brine spill on terrestrial plant communities, natural or agricultural, would probably be severe and possibly long term. Although we know of no research on such effects of geopressured brines per se, there is considerable literature on the effects of general salinity and of particular substances present in geopressured fluids on terrestrial plants. Studies of salinity effects on terrestrial plants and soils have been concerned principally with soluble seawater-derived salts of which the main ionic constituents are chloride, sodium, sulfate, magnesium, calcium, potassium, bicarbonate and bromide (see Phase I, Figure 9, Gustavson and McGraw, 1977). Of these ions, sodium and chloride are the most abundant in seawater. The following account on the effects of salts on terrestrial communities is based on Tandy and Caran (unpublished).

The influences of salts on coastal soil catenas are complex and synergistic, and have broad ecological importance. Salt concentration has marked effects on soil chemistry. Inland soils may naturally receive contributions of seawater-derived salts by such diverse means as eolian transport, flooding on the tidal reaches of streams, "storm" surge, and vadose water/groundwater emergence. Local differences in climate and soil characteristics affect the long-term extent of salinization.

Saline or halomorphic soils may be injurious or inhibiting to vegetation in two ways: "by reducing the amount of water that plants can take from the soil as a result of increase in (soil) osmotic pressure (Edminister and Reeve, 1957); and by direct toxic effects. The first of these processes occurs because of the exclusion of dissolved salts by root membranes which normally take in soil moisture but admit only a small percentage of the cations. Increases in salt concentration in the soil water solution raises "salt index" values, elevates osmotic pressures and makes the osmotic gradient more disparate. Further up-take of water with a low percentage of cations becomes energetically impossible. Growth is retarded in proportion to the osmotic pressure per se, and is largely independent of the cationic species present.

The toxic effects of saline soils on non-tolerant plants have been clearly demonstrated (Berg, 1950; Bower and Fireman, 1957; Edminster and Reeve, 1957; U.S.S.C.S., 1951, 1975; Richards, 1954; Viets and Hanway, 1957; and others). (Table 12.) Other deleterious consequences of a high percentage of salts may include reduced water absorption by clay

Table 12. Soil moisture salinity tolerances of various agricultural crops.*

Crop	Year NaCl *Mg/l (ppm)*			
	1946	1947	1948	Future limit
Spring barley (grain)	13,300	3,200	15,000	10,000
Sugarbeet (sugar)	7,300	1,500	9,000	7,000
Mangels (dry substance)	—	2,500	7,500	6,500
Oats (grain)	10,600	2,200	6,000	6,500
Lucerne	> 3,000	—	—	6,000
Spring wheat (grain)	8,300	2,600	3,200	4,000
Flax (straw)	2,500	—	4,800	4,000
Potatoes	3,100	1,100	4,200	3,000
Onions	2,500	—	3,200	2,500
Horse beans (seed)	< 3,000	3,400	3,100	2,000
Poppy (seed)	2,000	1,000	—	1,500
Peas (seed)	600	600	600	600
Beans–brown (seed)	400	500	400	500
Beans–white (seed)	—	400	400	400

Data are for the crops grown on drained land in the Netherlands which had been flooded by marine water during World War II. The soil could be considered a light marine clay containing 0 to 6% $CaCO_3$ and a little humus (2-4%). The water table was about 1 meter below the soil surface. NaCl was measured in soil moisture in the 5-20 cm layer at the time of the sowing period in spring and from which at least 75% of a normal yield was obtained.

*Modified from Berg (1950).

minerals (Marshall, 1950; MacEwan, 1950); inhibited movement of moisture through the solum (Childs and George, 1950); destructuring of the solum (Bodman and Fireman, 1950; Kovda, 1971; U.S.S.C.S., 1951, 1975; and Westerhof, 1950); reduced general nutrient absorption by soils (Peng et al., 1950); carbon and nitrogen metabolism (Lees, 1950) and denitrification of fertilizer applications (van Schreven, 1950); elimination or reduction of important soil fauna (Bornebusch, 1950) and flora; and retardation of the oxidative activity of various soil microorganisms (Treccani, 1950).

Salt concentration and its effects in soils may be heightened by various simultaneous but unrelated processes. Many deep-rooted halophytes increase the percentage of salts in the soil in which they grow; sodium and other cations are transported upward through the soil profile by absorption at depth and deposition at the surface by leaf-loss (Roberts, 1950; U.S.S.C.S., 1951). Extended periods of water saturation (rather than regular wetting-drying alternation) may encourage retention and prevent flushing of both chlorides and cations (Criddle and Haise, 1957; Deloffre, 1950; Dougall, 1950; Edminster and Reeve, 1957; Franki et al., 1965; Kovda, 1971; Malquori and Wiklander, 1950; Richards, 1950, 1954; Redman and Patrick, 1965; U.S.S.C.S., 1951, 1965, 1975). Cation fixation and base exchange ratios of various clay minerals may be altered almost irreversibly under natural conditions when sodium occupies a high percentage of the exchangeable cation positions, excluding essential cations (Bower and Fireman, 1957; MacGeorge and Fuller, 1950; Mehlich, 1950; U.S.S.C.S., 1951, 1975).

The deleterious and toxic effects of salt spray have been studied by a number of authors (Bourdeau and Oosting, 1959; Boyce, 1954; Doty, 1957; U.S. Forest Service, 1975; Moul, 1973; Oosting, 1954; Oosting and Billings, 1942; Thorne, 1954; Wells, 1939; Wells and Shunk, 1938). Similar effects have been observed in studies of de-icing compounds (containing sodium chloride and/or calcium chloride) used on highways, driveways and sidewalks in winter and which can produce local accumulations of saline water. Vehicular traffic may splash (or, in effect, "spray") this water onto the foliage of roadside vegetation, or the water may be taken up by the plant roots with toxic consequences (U.S. Forest Service, 1975: Elias and Irwin, 1976). Thorne (1954) recognized the existence of a distinct halophyte community of larger terrestrial vascular plants extending inland along the leeward shores of marine water bodies for a variable distance.

The above references illustrate the selection mechanism by which composition of natural "spray zone" floras are controlled by import of salt. Least tolerant species are excluded from areas immediately adjacent to the shoreline. The effect is not confined to coastlines of the open ocean but may be seen along the margins of secondary bays and estuaries (Boyce, 1954; Wells and Shunk, 1938).

The potency of salt spray in these studies is much greater than that which inhibits vegetation growth by direct contact on the seaward side of woody plants such as Live Oak (Bordeau and Oosting, 1959; Texas Highway Department, undated). Harcombe (1974) stated that salt spray apparently was the principal controlling factor in the distribution of his "coastal hardwoods" plant association, especially along the east margin of Trinity Bay. McGowen et al. (1970) noted that salt spray during Hurricane Celia killed trees a considerable distance inland from Copano Bay.

Salt crystals may also be deposited inland by eolian transportation. Such salt produced by evaporation of salt spray and of sea water (particularly along hypersaline bays where salinity and evaporation rates are very high), may be transported laterally over long distances or dispersed in atmospheric convection cells throughout the troposphere (Strahler, 1963). Saline precipitates on terrigenous clastic and organic particles are also subject to wind transport, as are salts absorbed by clay minerals (Marshall, 1950) or silt grains. These crystals and salt-bearing particles may be transported inland where they may affect the salinity of the receiving land surface or water body. Brown et al. (1976) and Huffman and Price (1949) have described the origin of active clay/sand dunes "by eolian accretion of saline clay pellets deflated from the surface of the (adjacent) wind-tidal flats." Resulting salinities of the clay/sand dune soils restrict the native vegetation to primarily halophytic forms (Brown et al., 1976; Franki et al., 1965; Johnston, 1955; U.S.S.C.S., 1976).

There are several salinized eolian deposition areas in the Texas coastal region, notably the broad south Texas "Eolian Plain" of Johnston (1955) and the "Saline Plain" of the Rio Grande delta of Price (1953). These areas are colonized exclusively by salt-tolerant vegetation (Bogusch, 1952; Ingles, 1964; Johnston, 1955, 1963); Johnston (1955) refers to the prairie and brush communities of the "Eolian Plain" (which corresponds generally to the "wind blown prairie" biologic assemblages of General Land Office of Texas (1976) and to the "Sarita-Falfurrias-Nueces Soil Association" of Godfrey et al. (1973)) as "salt spray climaxes". Faunal distribution corresponds closely to that of the vegetation. Fish (Hubbs, 1957), amphibians and reptiles (Blair, 1950; Raun and Gehlbach, 1972), birds (Lane and Tveten, 1974; Oberholser, 1974), and mammals (Blair, 1950; Davis, 1974; Kenagey, 1972) in the region demonstrate specialized adaptations for utilizing salt-affected habitats.

In aquatic animals, escape, reduction of contact, and regulation are indicated by Kinne (1967) as the basic mechanisms used to deal with salinity variations. Escape is limited to mobile organisms and assumes that better conditions are available elsewhere. Methods of reducing contact include reduction of surface area, mucus production, refuge (such as burrowing), withdrawal of sensitive body parts, and changes in activity levels. Regulatory responses include ionic regulation, volume regulation, and osmoregulation. These responses do not occur without some "cost" to the organism. Wohlschlag and Cameron (1967) have discussed the occurrence of metabolic depression in the pinfish (Lagodon rhomboides) and the high maintenance requirements of fish presented with stresses such as induced by industrial effluents. Such stress may have far-reaching effects as indicated by Snieszko (1974) who found that they can have an effect on outbreaks of infectious diseases in fish. Salinity tolerances of several species of aquatic animals from coastal Texas and Louisiana are presented in Table 13.

Rapidity of salinity fluctuations is a critical factor to many organisms that may be able to withstand high salinities if they are slowly adapted (Kinne, 1967). Eggs and larvae of teleosts are more susceptible to salinity variations than are adults due to the lack of development of organs for osmoregulation (gills, kidney, etc.). Increased salinities (those above 35,000 ppm) are detrimental to the eggs and larvae of most teleosts (Holliday, 1969; Lasker et al., 1972; May, 1975, 1976), so that salinity changes may have drastic effects in nursery areas. In addition, salinity is the deciding factor in the propagation of many species. Van Sickle et al. (1976) found that increased salinities in the Barataria Basin in Louisiana have allowed oyster (Crassostrea virginica) populations to move farther inland (spat fall occurs farther inland). This inland movement could be detrimental, as encroaching levels of pollution intrude seaward into areas of current and future oyster production. Hoese (1967) reported that in Texas bays, Blue Crabs (Callinectes sapidus) and White Shrimp (Penaeus setiferus) populations require low salinities for their young, as do oysters, for the destruction of predators which normally are found in waters of higher salinity. The droughts of the 1940's and 1950's evaporated the bay waters of Texas and led to the reduction of the crab, shrimp, and oyster populations. In addition there may be synergistic effects of salinity, temperature and heavy metals present in geothermal fluids as indicated by Jones (1975) in his study on mortality and osmoregulation in marine crustaceans.

Effects of elements, ions or compounds known to occur in geopressured brines on biological and industrial environments

The concentrations of 20 substances in geopressured brines and suggested ambient limits of concentration in biological and industrial

Table 13. Natural salinity tolerances for some species of coastal Texas and Louisiana animals. Some of the figures may represent salinity preferences rather than tolerances.

Species	Common Name	Salinity Range (ppm)			Source
		Low	High	Preference	
Menippe mercenaria	Stone Crab		35,000		Simmons (1957)
Rangia cuneata	Marsh Clam	0	24,900		Perret *et al* (1971)
Crassostrea virginica	American Oyster	10,000	30,000		Gunter (1967)
Thais haemastoma	Oyster Drill	1,700	25,900	>15,000	Perret *et al* (1971)
Penaeus setiferus	White Shrimp	25,000	45,000	<45,000	Simmons (1957)
		0	30,000		Lindall *et al* (1972)
		15,000	30,000		Gosselink *et al* (1976)
Penaeus duorarum	Pink Shrimp		69,000		Simmons (1957)
		15,000	25,000		Gosselink *et al* (1976)
Penaeus aztecus	Brown Shrimp	0	69,000		Lindall *et al* (1972)
		15,000	28,000		Gosselink *et al* (1976)
Palaeomonetes vulgaris	Grass Shrimp	25,000	45,000	<45,000	Simmons (1957)
Palaeomonetes pugio	Grass Shrimp	25,000	45,000		Simmons (1957)
Palaeomonetes intermedius	Grass Shrimp	20,000	60,000		Simmons (1957)
Callinectes sapidus	Blue Crab	20,000	60,000		Simmons (1957)
Brevoortia patronus	Largescale Menhaden	20,000	60,000		Simmons (1957)
		500	54,300		Renfro (1960)
Dorosoma cepedianum	Gizzard Shad	100	41,300		Renfro (1960)
Anchoa mitchelli	Bay Anchovy		80,000	<50,000	Simmons (1957)
		6,000	30,000		Gosselink *et al* (1976)
Cyprinodon variegatus	Sheepshead Minnow	5,000	75,000		Simmons (1957)
		5,000	28,000		Gosselink *et al* (1976)
Cynoscion arenarius	Sand Trout		45,000	<45,000	Simmons (1957)
		15,000	26,000		Gosselink *et al* (1976)
Cynoscion nebulosus	Spotted Seatrout	25,000	75,000	<60,000 (young)	Simmons (1957)
		19,000	27,000		Gosselink *et al* (1976)
Leiostomus xanthurus	Spot		60,000	<50,000	Simmons (1957)
		8,000	27,000		Gosselink *et al* (1976)
Micropogon undulatus	Atlantic Croaker		70,000		Simmons (1957)
		15,000	30,000		Gosselink *et al* (1976)
Mugil cephalus	Striped Mullet	1,400	75,000	<45,000 (spawn)	Breuer (1957)
		15,000	27,000		Gosselink *et al* (1976)
Mugil curema	White Mullet	25,000	50,000	<40,000	Simmons (1957)
		25,000	36,000		Moore (1973)

environments are summarized in Table 14. The concentrations of at least thirteen of these substances are above recommended standards for drinking water in at least one of the geopressured samples: silica, calcium, magnesium, strontium, copper, iron, manganese, sodium, potassium, ammonia, bicarbonate, chloride, and lead. Sixteen exceed standards for some terrestrial fresh water or marine organisms including beryllium, boron, cadmium, hydrogen ion (pH), and hydrogen sulfide in addition to the above substances, except perhaps strontium and lead. Concentrations of at least eight substances exceed some maximum industrial economic limits: silica, calcium, magnesium, strontium, sodium, bicarbonate, sulfate and chloride. These limits are suggested by the U.S. Environmental Protection Agency (USEPA, 1976) and/or McKee and Wolf (1963). Concentrations for geothermal water samples refer to undiluted wellhead concentrations--not to concentrations that might result from processing dilution, concentration or mixing after potential release to natural bodies of water.

We have no specific data on organic compounds present in geopressured fluids other than methane (CH_4). Future analyses should include organics--particularly the cyclic compounds and other toxic substances known from crude oil such as ethylene sulfide.[1]

Silica (SiO_2). An abundance of silica in water with other essential nutrients favors the growth of diatoms (algae). Blooms of diatoms synthesize silica into their tests (cell walls) and thereby lower the concentration of SiO_2 in the water. The diatom Asterionella requires silica for growth in ponds. Silica in natural waters at concentrations of 1 - 40 mg/l does not appear to cause adverse physiological effects in humans. Difficulties may arise from turbidity at concentrations above 50 mg/l. Limits for industrial uses are in many cases much more severe than those for biological welfare. Boiler feed water tolerances may be as low as 0.3 mg/l and turbine blade tolerances for steam as low as 0.1 mg/l. Silica concentrations in geopressured waters range from less than to almost twice the recommended biological standards. These geothermal concentrations are as high as 900 times the recommended limit for steam turbine blades (McKee and Wolf, 1963).

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[1] After this text was drafted, we received a copy of Kharaka, Callender and Carothers (1977) which contains considerable chemical data on geopressured brines. Their data indicate ionic concentrations higher than those shown in Table 14.

Table 14. Concentrations of 20 substances in geopressured brines and suggested ambient limits in biological and industrial environments.*

Element, ion, or compound	*Geopressured formation waters*						Maximum safe limit in domestic water supplies	Maximum economic limit in industrial water supplies (*ppm*)	Maximum safe limit in irrigation water supplies or aquatic environments
	Gardiner Well #1	Mayo Owens Well #1	Portland Well #A3	W.F. Lehman Well #1a	Lehman Gas Unit #1a	LR-67-01-802			
Silica (SiO_2)	87	34	93	68	71		50 (turbidity problems)	0.3-40.0 (boiler feed); 0.1 (turbine blades); 20-100 (pulp and paper mills)	10-50 suggested limit
Calcium (Ca)	2,000	200	89	71	52		30 (drinking and cooking) 75-200 maximum limit	10-500	Often desirable for irrigation, depending on soil type
Magnesium (Mg)	235	31	15	90	110		30-125 0.05 mg/l recommended	5-300	24 to protect underground water basins
Strontium (Sr)	380	25	7.0	126-252	38-72	95	~30 (drinking and cooking) 75-200 maximum limit	~10-500	
Copper (Cu)				0.17-0.38	0.11-930	0.01	1.0		0.0018-7.5 depending on species and conditions
Iron (Fe)	8.0	70	2.3	8.4-16.8	2.7-3.8	16	(0.3)[1]		1.0 freshwater
Manganese (Mn)	2.7	1.4	0.16	ND	ND	<0.02	(0.05)[1]		0.2 for irrigation water on acid soils 0.1 for protection of consumers marine molluscs
Sodium (Na)	24,000	9,250	6,500	16,000	14,000		Harmful to humans suffering from cardiac, renal and circulatory disease 10-115 = conservative limit	50	106-212 in sprinkler irrigation may cause serious foliage damage Cumulative deterioration of soil likely - 2,000 limit for livestock water
Potassium (K)	300	70	68	230	150		1,000-2,000 extreme limit for drinking		Essential in small quantities for stock and plant nutrition
Rubidium (Rb)	0.80	0.30	0.30						1.4-100 freshwater
Ammonia (NH_3)	26	11	5.8						Toxic to fish 0.02 freshwater
Bicarbonate (HCO_3)	520	1,200	1,600	526	381		0-150 desirable or permissible	100-200	200 causes decline of sugar in apples and pears
Sulfate (SO_4)	0.6	22	84	30	30		200-400	20-300	576-960 maximum limit may cause precipitation of calcium and, thus, toxicity
Chloride (Cl)	40,500	14,000	9,270	25,000	21,000		Harmful to humans with heart and kidney disease; 5-600 depending on climate and other factors - USPHS recommended limit is 250	20-1,500	1,500-3,000 limit for livestock watering
Beryllium (Be)				0.13-0.26	0.11-0.22		?		0.011-1.100 freshwater; 0.1-0.5 for irrigation depending on soil type
Boron (B)	30	24	62				Total at 5-45 grams in drinking water OK		Deleterious for certain crops at the following concentrations: ● In excess of 0.5: pecans, artichokes, plums, pears, apples, cherries, grapes, peaches, oranges, avocados, grapefruit, and lemons ● 1.0-2.0: potatoes, tomatoes, peas, wheat, corn, oats, and lima beans ● 2.0-4.0: asparagus, date palms, sugar beets, alfalfa, onions, turnips, cabbages, lettuce, and carrots
Cadmium (Cd)						0.008	0.01		0.0004-0.012 freshwater; 0.005 marine
Lead (Pb)						<0.2	0.05		0.0052-5600 fish, depending on species and conditions
Hydrogen sulfide (H_2S)	0.32	ND	ND						0.002 freshwater and marine
pH (acidity)	6.3	6.7	6.8				5-9		6.5-9.0 freshwater; 6.5-8.5[2] marine

[1] based on aesthetic criteria [2] . . . but not more than 0.2 units outside normally occurring range.

*Data on brines are from Kharaka, Callender and Wallace (1977), Gustavson and Kreitler (1976), and unpublished data of the Bureau of Economic Geology, University of Texas. Suggested ambient units are from McKee and Wolf (1963) and U.S. Environmental Protection Agency (1976).

Calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K^{+}) and chloride (Cl^{-}). These are among the principal ionic constituents of sea water, and their ecological properties are evident in the previous discussion on salinity (see also Table 14).

Strontium (Sr). This element is chemically related to calcium, magnesium and barium. It is present in plant and animal tissues in trace concentrations, but it occurs at much higher concentrations in bone structures. It does not appear to be an essential plant nutrient, but it may be necessary for growth of animals--particularly for calcification of bones and teeth. Toxicity of non-radioactive strontium is probably on the same order of magnitude as calcium. Sea water may contain 8.5 - 10 mg/l. It is not absorbed readily by soils and may be expected to travel with ground waters. Concentrations in geopressured waters range from approximately one-fourth to 12 times recommended drinking water standards. Geopressured-geothermal fluids contain from about the same concentration to 38 times that found in sea water (McKee and Wolf, 1963).

Copper (Cu). This is an essential trace element for plants and animals. Prolonged oral intake of excessive quantities of copper may result in liver damage in humans. Required daily human intake is 0.1 mg for children and 2 mg for adults (Sollman, 1957). Because copper in excess of 1 mg/l may impart some taste to water, USEPA (1976) has recommended a drinking water limit of 1 mg/l. The toxicity of copper to aquatic life is dependent on the species, stage of development, alkalinity, pH and concentration of organic compounds. At lower alkalinity, copper is usually more toxic. Recommended standards for freshwater or marine environments are 0.1 times a 96-hour LC50 (the concentration which kills 50% of the organisms tested during 96 hour trial periods) based on sensitive resident species. These range from 0.0018 mg/l for one month old Chinook Salmon (Oncorhynchus tshawytscha) to 7.5 mg/l for Mosquito Fish (Gambusia affinis). See USEPA (1976) for data on other species many of which occur on the Gulf Coast. The 930 mg/l concentration of copper in the Lehman Gas Unit #1[a] sample is more than 100 times in excess of the standards for the most tolerant aquatic species.

Iron (Fe). This is also an essential trace element for plants and animals. Ferrous (Fe^{++}) and Ferric (Fe^{+++}) ions are the principal forms of concern in aquatic environments. The ferric form is almost insoluble in water. In the presence of dissolved oxygen, iron in water can precipitate as an hydroxide [$Fe(OH)_3$]or as ferric oxide (Fe_2O_3). Both of these form as gels or flocs that may be detrimental to aquatic life. They can settle to form flocculant materials that cover stream bottoms and destroy bottom-dwelling invertebrates, plants or incubating fish eggs. These flocs can consolidate to form cement-like materials and fuse bottom gravels into pavement-like areas unsuitable as spawning sites for nest building fishes. Iron is objectionable in water supplies for domestic or industrial use because of its taste and staining properties (Riddick _et al._, 1958). It can be tasted in concentrations of 1.8 - 3.4 mg/l.

Daily human nutritional requirement is 1 - 2 mg, but intake of large quantities averaging 16 mg is necessary because of poor absorption (Sollman, 1957). The recommended iron criterion for domestic water is based principally on aesthetic criteria related to its staining properties rather than on toxicological significance.

Experimental toxic levels for freshwater organisms range from 0.32 to 2.0 mg/l. Marine life has not been adequately studied to determine criteria. Dissolved iron readily precipitates in alkaline sea water. Settled iron flocs may have adverse effects on important benthic commercial mussels and other shellfish resources (USEPA, 1976).

All geopressured samples in Table 14 exceed the freshwater limits--that from the Mayo Owens well by a factor of 70.

Manganese (Mn). This is a vital micro-nutrient for plants and animals. The average human intake is 10 mg/day (Sollman, 1957). Very large doses can cause some disease and liver damage (McKee and Wolf, 1963). The manganese criterion for domestic water is based on aesthetic grounds related to its taste and staining properties.

Tolerances of freshwater organisms range from 1.5 to over 1000 mg/l. Most natural freshwater environments have concentrations of less than 1 mg/l. There are few data available for marine organisms. Sea water usually contains about 0.002 mg/l (Fairbridge, 1966). Manganese is rapidly assimilated and bioconcentrated into nodules that are deposited on the sea floor. A problem may be concentration in the edible portion of molluscs. Bioaccumulation factors as high as 12,000 have been reported (National Academy of Sciences, 1974). The marine water criterion of 0.1 mg/l is to protect against a possible health hazard to humans because of manganese accumulation in shellfish.

At concentrations of about 1 to a few milligrams per liter, manganese may be toxic to plants from irrigation water applied to soils with pH lower than 6.0. Long term irrigation on other soils with water containing 10 mg/l may cause problems (NAS, 1974). The criterion of 0.2 mg/l is for acidic soils.

Among the geopressured water samples, the manganese concentration of the Gardiner Well is 27 times the marine criterion and 13 times that for irrigation water on acidic soils. None of the samples contains a concentration of manganese which alone would be likely to cause problems for freshwater organisms.

Ammonia (NH_3). This is a biologically active compound and is found in most natural waters as a normal biological degradation product of nitrogenous organic matter. When dissolved in water, some ammonia (NH_3) reacts with water to form ammonium ions (NH_4^+). Toxicity of aqueous solutions of ammonia is caused by NH_3. Its concentration is affected by pH, temperature and total ion concentration. NH_3 concentration increases with increasing temperature and decreases with increasing salinity in dilute saline waters but may reach high levels in highly alkaline waters.

Toxic levels for fish range from 0.2 to 2.0 mg/l for exposures of relatively short duration (USEPA, 1976). Ammonia concentrations in geopressured water samples exceed the freshwater criterion by factors of 290 to 1300.

Bicarbonates (HCO_3^-). This is a biologically important ion and may occur in natural waters via solution of CO_2 or decomposition of organic matter. Its concentration in water depends on equilibrium reactions that are dependent on carbonate concentration and pH. At medium to low pH values (less than 7) CO_2 tends to be produced in water containing dissolved bicarbonates. Concentrations of bicarbonate up to 150 mg/l are not known to cause biological problems. A concentration of 700 mg/l may be unhealthful for humans. Marked declines of vigor of apple and pear trees have been observed after use of irrigation water for a number of years containing 200 mg/l. In irrigation water, bicarbonates alone do not cause difficulty, but by aiding in the precipitation of calcium carbonate they adversely affect the sodium ratio. Industrial limits include 100 mg/l (sugar refining and steam boilers) and 200 mg/l (textiles and pottery) (McKee and Wolf, 1963).

Concentrations of bicarbonate in geopressured waters range from about 3.5 to 16 times recommended limits. Because of the slightly acidic pH of these waters, carbon dioxide (CO_2) would tend to be released from them via bicarbonate decomposition.

Sulfate ($SO_4^=$). This ion is an essential nutrient for plants. Water containing less than 0.5 mg/l will not support algal growth. Of U.S. natural freshwaters, 95% contain less than 90 mg/l and 50% less than 32 mg/l. Normal concentrations in seawater are almost

2450 mg/l. Sulfates occur naturally in waters as a result of leaching from gypsum and other common minerals. They may occur as the oxidized state of organic matter in the sulfur cycle, and these may serve as energy sources for sulfate-splitting bacteria. Drinking water standards of 200-400 are based primarily on a laxative action on new users. Some water supplies in the USSR contain as much as 1295 mg/l without apparent ill effects on the local population. For irrigation waters, 960 mg/l is the maximum level recommended. A threshold limit of 1000 mg/l has been recommended for livestock and wildlife watering. Industrial limits vary from 20 mg/l for sugar refining to 250 mg/l for ice making (McKee and Wolf, 1963).

The concentrations of sulfates in geopressured waters are considerably less than standards for drinking or irrigation water or ambient sea water concentrations. Some samples are below and others above most ambient freshwater levels. Geopressured concentrations of from 1/29th to 1/4000th the ambient concentration of sea water might be expected to cause physiological problems for marine organisms.

Beryllium (Be). This is a relatively rare element and is not likely to occur in natural waters. Freshwater samples from the U.S. average 1.9×10^{-4} mg/l and sea water concentrations are 6×10^{-7} mg/l.

Ingestion of beryllium by animals including humans does not appear to be harmful, but there is a major toxic hazard to humans from beryllium dusts and fumes in metallurgical industrial facilities at concentrations of less than 0.001 mg/m^3 of air. Beryllium toxicity to freshwater fish is dependent on water hardness. The standard for hard water of 1.1 mg/l is 100 times that for soft water--0.011 mg/l because of this relationship. Standards have not been determined for marine organisms. Some marine species are known to concentrate the element as much as 1000 fold. Beryllium can inhibit photosynthesis in terrestrial plants, it is toxic to some varieties of citrus seedlings and it can reduce growth and yield of bush beans, tomatoes, peas, soybeans, lettuce, alfalfa, ladino clover, mustard and kale. It is more toxic in acidic than in alkaline soils. Standards are 0.1 mg/l for irrigation waters on all soils except neutral to alkaline fine-textured soils for which 0.5 mg/l is the recommended maximum (USEPA, 1976).

Beryllium concentrations in geopressured water samples analyzed by Gustavson and Kreitler (1976) are as much as 1400 times the ambient concentrations of average natural freshwaters and 400,000 times ambient marine concentrations. Geopressured concentrations exceed standards for soft freshwater environments and for irrigation water except that used on neutral to alkaline soils. They do not exceed standards for hard freshwaters. There might be a health problem for humans if beryllium dusts were dispersed as an indirect result of use of geopressured water in wet cooling towers.

Boron (B). This is not found in its elemental form in nature, but rather as a borate salt. It is an essential trace element for growth of plants, but there is no evidence that it is required by animals. Mean U.S. river and lakewater concentration is 0.1 mg/l. Sea water contains approximately 4.5 mg/l. Minnows can tolerate 6 hour exposures to concentrations of almost 18,000 mg/l (USEPA, 1976).

Boron in low concentrations may be toxic to terrestrial plants (Weres, Tsao and Wood, 1977). Sensitive crops have shown toxic effects at 1 mg/l or less (USEPA, 1976). Boron is absorbed by plant roots and is concentrated in leaf tissue. These concentrations eventually reach levels which are toxic to the plant (Table 15). The recommended standard for long-term irrigation of sensitive crops is 0.75 mg/l.

Boron concentrations in geopressured waters are 30 to 80 times the recommended irrigation limits and 5 to 14 times the ambient concentration of sea water. At the Geysers geothermal field in California, leaf damage has been observed in Bigleaf Maple (Acer macrophyllum), Douglas Fir (Pseudotsuga menziesi), and oaks (Quercus spp.) which have been exposed to cooling tower drift containing borate (Weres, Tsao and Wood, 1977). The soil concentrations of borate thought to have caused this are estimated at about 6.6 mg/l (Sharp, 1976). Concentrations in geopressured fluids are sometimes almost 10 times that concentration.

Cadmium (Cd). Biologically cadmium is unessential, nonbeneficial and potentially highly toxic. It is deposited and accumulated in various human tissues. Industrial production and use of the metal increased in the decades between 1956 and 1976, and cases of acute cadmiosis have been documented. The metal may function in various human pathological processes including testicular tumors, renal dysfunction, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age and cancer. Toxic effects may result from inhalation or ingestion. The drinking water standard is 0.001 mg/l.

Most fresh waters contain less than 0.001 mg/l and the mean concentration for sea water is 0.00015 mg/l. Fish and some invertebrates are sensitive to low levels of cadmium in water. Salmonids and cladocerans appear to be most sensitive. Increased

Table 15. Time necessary to produce boron toxicity symptoms with 10 ppm_v in solution, and boron concentrations in leaves of various species.*

Plant	Time days	Concentrations		
		Necrotic ppm_w	Chlorotic ppm_w	Green ppm_w
Bean	8	1960-2510	970-1300	630-680
Alta fescue	8	1510-8200	--	50-760
Bluegrass	12	1860-6800	--	40-960
Bermuda grass	16	1380-5770	--	40-700
Cotton	16	780-2290	410-610	710-1040
Tomato	8	3900-5150	2280-3130	400-970
Corn	16	1220-12,860	490-1160	360-790
Sweet gum	20	2610-4330	760-850	490-980
Carrot	20	2000	--	470-960
Barley	6	1170-5030	--	90-170

*From Weres, Tsao, and Wood (1977) based on Oertli and Kohl (1961).

water hardness and/or alkalinity decrease toxicity of cadmium in acute freshwater mortality tests, but may have less of an effect at low cadmium levels.

Adult oysters (Crassostrea virginica) exposed to 0.01 mg/l cadmium for four months accumulated 18 mg/kg of the metal in wet whole meat, which exceeds the human emetic threshold of 13 to 15 mg/kg.

The recommended criteria necessary to protect fish and other aquatic life are more stringent than those necessary to protect public water supplies or other uses. Because of effects of water hardness and species on toxicity, different criteria are recommended: for cladocerans and salmonid fishes 0.0004 mg/l in soft water, 0.0012 mg/l in hard water; for other less sensitive freshwater organisms 0.004 mg/l in soft water, 0.012 mg/l in hard water. The marine criterion is 0.005 mg/l (USEPA, 1976).

The cadmium concentration of 0.008 mg/l from the geopressured water sample LR-67-01-802 exceeds the ambient standards for marine and many freshwater organisms, and it approaches the limit for drinking water (see Table 14). It is not known whether this cadmium originated in the geopressured formation water, from the well casing, or from some other source, but its presence is of biological concern.

Lead (Pb). This element exists in nature principally as lead sulfide (galena); other common forms are lead carbonate (cerussite), lead sulfate (anglesite) and lead chlorophosphate (pyromorphite). Stable complexes can result from the interaction of lead with the sulfhydryl, carboxyl and amine coordination sites of molecules found in living matter. Aqueous solubility of lead ranges from 0.5 mg/l in soft water to 0.003 mg/l in hard water. Toxicity is affected by pH, hardness, organic materials and other metals. General environmental concentrations are thought to have increased as much as 10 times during world industrialization.

Lead is not known to have any desirable nutritional effects or other biologically beneficial properties. It is toxic and often accumulates in tissues of man and other animals. Irreversible brain damage often results from lead intoxication in children. Toxic effects include anemia, neurological dysfunction and renal impairment. Biochemical effects include inhibition of erythrocyte delta-aminolevalinic dehydrase (ALAD) activity, increased urinary excretion of delta-aminolevalinic and increased blood lead concentration.

Toxicity of lead to freshwater organisms varies with species, pH and water hardness. Generally, salmonids are most sensitive to lead in soft water. Differences in toxic concentrations between very soft and very hard water are 100 to 500 times because of solubility differences. The criterion for safe concentration for fish species is 0.01 times the acute 96-hour LC_{50} value expressed as dissolved lead. It is probable that salmonids, minnows and catfish are more sensitive to lead than are bass, sunfish and perch. Tests for toxicity should be performed on the more sensitive species when experimentally establishing quantitative standards for a particular aquatic environment.

Some marine organisms can concentrate lead in sea water. Calabrese *et al.* (1973) found 48-hour LC_{50} of 1730 and 2450 mg/l for oyster eggs (*Crassostrea virginica*). This oyster species has a remarkable ability to concentrate lead:

> Pringle *et al.*, 1968 [exposed] them to flowing sea water containing lead concentrations of [0.025 mg/l, 0.050 mg/l, 0.100 mg/l and 0.200 mg/l]; after 49 days, the total accumulation of lead amounted to 17, 25, 75 and 200 ppm (wet weight), respectively, and those oysters exposed to the two highest lead levels, upon gross examination, showed considerable atrophy and diffusion of the gonadal tissue, edema, and less distinction of hepatopancreas and mantle edge (USEPA, 1976).

Concentrations of 10 - 25 mg/l of lead nitrate have been found to cause toxic effects in terrestrial crop plants (oats, tomatoes, beans). Lead concentrations in soils are usually 0.05-5.0 mg/l.

The concentration of lead in geopressured water sample LR-67-01-802 is given as "less than 0.2 mg/l". The origin of this lead is uncertain (see comments above re cadmium). A concentration of 0.2 mg/l is four times the domestic water supply limit. This is above the toxic limits for some fish species at certain conditions and below those for others (see Table 5 in USEPA (1976), pp. 166-169). A concentration of 0.2 mg/l would probably be physiologically unavailable to terrestrial plants. Because of the toxic effects of lead and the ability of organisms to concentrate it in their tissues, the potential presence of lead in geopressured waters is of concern.

Hydrogen sulfide (H_2S). This is a soluble and highly poisonous gaseous compound which smells like rotten eggs. It is biologically active and is produced principally by anaerobic degradation of organic sulfur compounds and inorganic sulfates. Decomposition of naturally deposited organic matter is a major source of H_2S.

When dissolved in water, H_2S may dissociate to form hydrosulfide (HS^-), hydrogen (H^+), and sulfide (S^{2-}) ions. The proportions of these depend on pH. H_2S is the most toxic form, and it predominates at acidic pH's (below 7). H_2S is oxidized to sulfates or sulfur by natural biological systems in well aerated water. The hazard of H_2S to aquatic life depends on temperature, pH and dissolved oxygen. It is most toxic at low temperatures, low pH and low oxygen conditions. Fish behaviorally avoid H_2S if they have an escape route. Toxic concentrations for fish range from 0.002 - 0.047 mg/l depending on the species and conditions (USEPA, 1976).

The concentration of H_2S of 0.32 mg/l in the Gardiner well #1 sample exceeds the limit for freshwater fish (0.002 mg/l) by a factor of 160. It should be noted that 0.32 mg/l is far below the H_2S concentrations found in some geothermal wells from other areas (see Table 7). Problems of H_2S in the gaseous phase will be discussed below under "noncondensable gases".

pH (acidity, hydrogen ion "concentration"). This is a reflection of hydrogen ion concentration--the higher the pH value, the lower the H^+ concentration. The following is from USEPA (1976):

> "The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts and gases. The principal system regulating pH in natural waters is the carbonate system which is composed of carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ions ($CO_3^=$)...
>
> pH is an important factor in the chemical and biological systems of natural waters. The degree of dissociation of weak acids or bases is affected by changes in pH. This effect is important because the toxicity of many compounds is affected by the degree of dissociation. One such example is...hydrogen sulfide (H_2S) (Jones, 1964).
>
> The solubility of metal compounds contained in bottom sediments or as suspended material also is affected by pH.... under anaerobic conditions...pH [is] an important parameter involved in releasing manganese from bottom sediments (Delfino and Lee, 1971).
>
> A review of the effects of pH on freshwater fish has been published by the European Inland Fisheries Advisory Commission (EIFAC, 1969). The Commission concluded: 'There is no definite pH range within which a fishery is unharmed and outside

which it is damaged, but rather, there is a gradual deterioration as the pH values are further removed from the normal range. The pH range which is not directly lethal to fish is 5 - 9; however, the toxicity of several common pollutants is markedly affected by pH changes within this range, and increasing acidity or alkalinity may make these poisons more toxic. Also, an acid discharge may liberate sufficient CO_2 from bicarbonate in the water either to be directly toxic, or to cause the pH range 5 - 6 to become lethal.' ...

Based on present evidence, a pH range of 6.5 to 9.0 appears to provide adequate protection for the life of freshwater fish and bottom dwelling invertebrate fish food organisms. Outside of this range, fish suffer adverse physiological effects increasing in severity as the degree of deviation increases until lethal levels are reached.

Conversely, rapid increases in pH can cause increased NH_3 concentrations which are also toxic. Ammonia has been shown to be ten times as toxic at pH 8.0 as at pH 7.0 (EIFAC, 1969).

The chemistry of marine waters differs from that of fresh water because of the large concentration of salts present. In addition to alkalinity based on the carbonate system, there is also alkalinity from other weak acid salts such as borate. Because of the buffering system present in sea water, the naturally occurring variability of pH is less than in fresh water. Some marine communities are more sensitive to pH change than others (NAS, 1974). Normal pH values in sea water are 8.0 to 8.2 at the surface decreasing to 7.7 to 7.8 with increasing depth (Capurro, 1970). The NAS Committee's review (NAS, 1974) indicated that plankton and benthic invertebrates are probably more sensitive than fish to changes in pH and that mature forms and larvae of oysters are adversely affected at the extremes of the pH range of 6.5 to 9.0. However, in the shallow, biologically active waters in tropical or subtropical areas, large diurnal pH changes occur naturally because of photosynthesis. pH values may range from 9.5 in the daytime to 7.3 in the early morning before dawn. Apparently these communities are adapted to such variations or intolerant species are able to avoid extremes by moving out of the area.

For open ocean waters where the depth is substantially greater than the euphotic zone, the pH should not be changed more than 0.2 units outside of the

> naturally occurring variation or in any case outside the range of 6.5 to 8.5. For shallow, highly productive coastal and estuarine areas where naturally occurring pH variations approach the lethal limits for some species, changes in pH should be avoided but in any case not exceed the limits established for fresh water, i.e., pH of 6.5 to 9.0. As with the freshwater criteria, rapid pH fluctuations that are due to waste discharges should be avoided. Additional support for these limits is provided by Zirino and Yamamoto (1972). These investigators developed a model which illustrates the effects of variable pH on copper, zinc, cadmium, and lead; small changes in pH cause large shifts in these metallic complexes. Such changes may affect toxicity of these metals.
>
> For the industrial classifications considered, the NAS report (NAS, 1974) tabulated the range of pH values used by industry for various process and cooling purposes. In general, process waters used varied from pH 3.0 to 11.7, while cooling waters used varied from 5.0 to 8.9. Desirable pH values are undoubtedly closer to neutral to avoid corrosion and other deleterious chemical reactions. Waters with pH values outside these ranges are considered unusable for industrial purposes.
>
> The pH of water applied for irrigation purposes is not normally a critical parameter. Compared with the large buffering capacity of the soil matrix, the pH of applied water is rapidly changed to approximately that of the soil. The greatest danger in acid soils is that metallic ions such as iron, manganese or aluminum may be dissolved in concentrations which are subsequently directly toxic to plants. Under alkaline conditions, the danger to plants is the toxicity of sodium carbonates and bicarbonates either directly or indirectly (NAS, 1974).
>
> To avoid undesirable effects in irrigation waters, the pH should not exceed a range of 4.5 to 9.0."

The pH values of geopressured water samples are generally within the suggested limits for drinking water, freshwater and estuarine organisms, and irrigation water; but they are below those for normal sea water. The slightly acidic pH of geothermal fluids would tend to make other components (copper, manganese, bicarbonate, cadmium, lead, hydrogen sulfide) more toxic because of synergistic effects.

Other substances. Some toxic substances which are known from geothermal fluids from other parts of the world--bromine (Br), cesium (Cs), mercury (Hg), arsenic (As), iodine (I), zinc (Zn), hydrogen flouride (HF), flourine (F_2), antimony (Sb), barium (Ba), and radon-222--are not known from geopressured fluids. We do not have analyses for many of these substances from geopressured wells. Such analyses are in progress by Kharaka and others at the U.S. Geological Survey, Menlo Park, California (Kharaka, personal communication). One would expect some major differences between the chemical composition of geopressured waters and those of other geothermal areas because of differences in geochemistry of parent rocks. Geopressured waters are found in sedimentary rocks whereas other geothermal fluids are often associated with volcanic formations.

Effects of oil field brines on terrestrial plant communities. The Saratoga oil field is one of the oldest in Texas. It was discovered about 1900. During the early exploitation of the field, there was little concern for damage to surface ecological systems. For many years, salt water was disposed of in local freshwater streams or in pits. The Barren land is apparently the result of exposure to brines which occurred many years ago and it is striking that plant communities have not become reestablished in the area (Figure 28). This region receives approximately 140 cm of rainfall per year, and one would have expected these soils to have been flushed of salt pollutants.

With regard to the presently occurring surface leakage, there may be substances in these releases other than brines and hydrocarbons that naturally occur in the oil deposits. This is partially because in situ combustion is being used to fire flood many of the wells in this area in order to decrease the viscosity of hydrocarbons and enable oils to be pumped to the surface. Injection of salt water for secondary recovery of oil is also practiced in some of these wells. Salt water is presumed to be disposed of by injection into the cap of salt domes of the area (Hargis, personal communication).

Other potential effects of brines on marine organisms. The unusual ionic balance of geothermal waters may produce effects on marine organisms other than those related directly to salinity. May (1976) found that poor survival of Gulf Croaker (Bairdiella icistia) from the Salton Sea was related to the unusual ionic composition of that water body. Relatively little is known of the effects of high concentrations of some components of geothermal fluids. Although the effects of boron on vegetation are partially known, knowledge of the effects of high boron concentration on aquatic organisms is meager. Thompson et al. (1976) investigated toxicity and uptake and made a survey study of boron in the marine environment, but their results were rather inconclusive regarding effects of high concentrations.

In summarizing the possible effects of geothermal brine releases to the environment several points should be made:

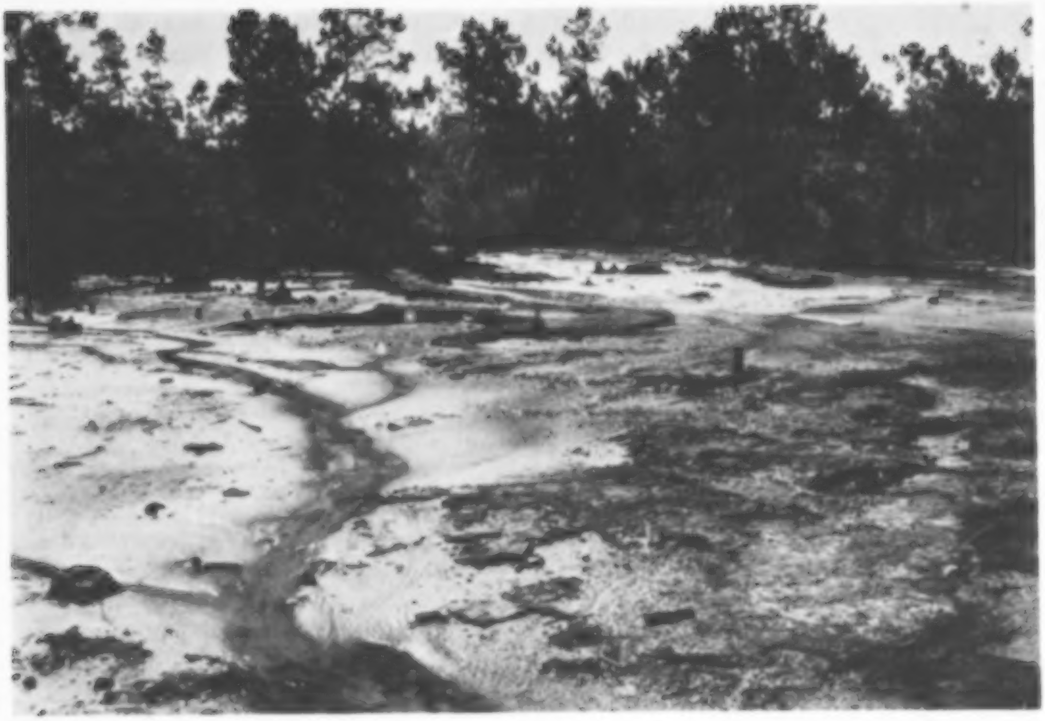

Figure 28. Part of the Saratoga Oil Field, Hardin County, Texas, March, 1977. Much of the area is devoid of vegetation, apparently the result of large-scale brine and/or hydrocarbon spills 30 to 80 years ago. Photograph by M. Tandy.

(1) Though plant and animal species of the salt marsh environment are able to withstand salinities up to about 40,000 ppm, brackish and freshwater species are unable to tolerate such high salt concentrations. In situations where brines are dumped into these systems, survival may be reduced. Heffernan et al. (1971) found that oil field brines emptying into Chiltipin Creek and Copano Bay in Texas produced 100% mortality at concentrations of over 40,000 ppm in Brown Shrimp (Penaeus aztecas), White Shrimp (P. setiferus), and Blue Crab (Callinectes sapidus) megalops.

(2) Gradual rather than abrupt changes are better tolerated.

(3) Larvae and juveniles of a species may find it hardest to adjust to high salinities, salinity fluctuations, and/or unusual ion balances.

(4) Circulation and mixing in the bay and estuarine systems are extremely important in reducing the impacts of brine effluents.

(5) Temperature is an extremely important factor in brine considerations because it may compound salinity effects. Synergistic effects of temperature and salinity were demonstrated by May (1975) for Gulf Croaker (Bairdiella icistia) eggs and larvae.

(6) The duration of the stress produced by the brines is an important consideration. Some species may withstand stressed conditions for short periods, but may not be able to tolerate them for extended periods.

(7) Disruptions of one important species may have far-reaching effects on the entire ecological chain in any given area. For example, Spotted Seatrout (Cynoscion nebulosus) may be able to tolerate high salinities, but would be required to move to other areas if their food source were destroyed by adverse conditions.

Pipeline scalings

Scale deposits on the interior surfaces of pipelines, turbine blades, etc. have been major engineering problems with some geothermal operations (Hanck and Nekoksa, 1975; Tolivia et al., 1975; Wahl and Yen, 1975). These scalings may be precipitates of substances present in geothermal formation waters or corrosion products resulting from interaction of brines with metallic structures. Scalings have been a major reason for shutdowns at experimental normal pressured hydrothermal projects in California's Imperial Valley. At the Niland facility it has been necessary to replace structures relatively frequently because of massive deposition and corrosion. Pipelines, generators, etc. must be periodically cleaned of such deposits. Scaling and corrosion can thus generate both liquid and solid wastes which could be hazardous to ecosystems.

Corrosion introduces substances into geothermal fluids and scalings which may not be present, or which may be present at much lower concentrations, in formation waters. These substances may include compounds of aluminum, chromium, copper, iron, molybdenum, titanium, vanadium, zinc and possibly others (Tolivia et al., 1975). Other compounds may be deliberately added to geothermal brines as corrosion inhibitors including compounds of iron and nickel and "Cataban" (Hanck and Nekoksa, 1975).

Potential biological effects of the various compounds mentioned above differ greatly. Some of the corrosion products such as aluminum hydroxide and oxides and sulfides of copper and iron may be so insoluble that they might pose little threat to ecosystems if released to them other than increasing turbidity (see Table 16). Other compounds of the above elements under various conditions can be toxic (see McKee and Wolf (1963) and USEPA (1976)).

Thermal discharge

Like all other thermal electric generating plants, geothermal power plants produce large amounts of hot waste water. Efficiencies of various types of power plants are as follows: fossil fuels, 36-40%; nuclear, 32-34%; geothermal dry steam, 14-16%; and geothermal flashed steam, about 11% (see Table 17). Geothermal generating plants yield a greater amount of waste heat per unit of electrical energy produced than do fossil or nuclear fueled plants because the temperature and pressure (hence the enthalpy) of natural steam is much lower than that of steam produced in a boiler (U.S. Department of the Interior, 1976b). If geothermal brines are discharged into holding ponds, a large amount of heat may be added to the local environment.

Heat will be discharged from all activities associated with geopressured exploitation including well heads, pipelines, power plant proper, and cooling structures. Heat loss from wells and pipelines will be minimized for engineering and resource utilization reasons. Small amounts will still be radiated to the surrounding environment. Much larger amounts of heat are discharged at the generating facility, and cooling technologies will be required. Unlike other power generating facilities, geothermal plants (with the exceptions of binary and total flow systems) produce enough water to provide a cooling loop without using external water supplies. It is also possible for normal

Table 16. Results for X-ray diffraction for corrosion products and deposits on specimen surface in condensate at the Cerro Prieto geothermal facility near Mexicali in the Mexican portion of the Salton Trough.*

Materials	Low velocity test		High velocity test	
Deoxidized copper	Cu_2S	+++	Cu_2S	+++
			$Cu_{1.96}S$	(+)
			Cu_2O	(+)
Aluminum	FeS_2	+++	FeS_2	+++
	SiO_2	++	S	+
	$Al(OH)_3$ (Bayerite)			
	N.S.I.†	(+)		
Naval brass	$Cu_{1.96}S$	+++	$Cu_{1.96}S$	+++
	βZnS	+	FeS_2	++
	SiO_2	+	N.I.S.†	+
Carbon steel	Fe_3O_4	+++	FeS_2	+++
	N.I.S.†	+~++	Fe_3O_4	++
			$\alpha Fe_2O_3H_2O$ (Goethite)	++
			N.I.S.†	
18-8Stainless steel	FeS_2	+++	FeS_2	+++
	SiO_2	(+)	S	++~+++
12 Cr steel	FeS_2	+++	FeS_2	+++
	SiO_2	+	S	+
			$\alpha Fe_2O_3H_2O$ (Goethite)	+
			Fe_3O_4	(+)

+++ *very much*
++ *much*
+ *slight*
(+) *very slight*
† Not identified structure

* From Tolivia *et al.* (1975).

Table 17. Water and heat flows in three geothermal plant cycles.*

	Steam 185°C (Geysers)	Water 210°C (Double Flash)	Water 160°C (Binary)
Thermodynamic efficiency (%)	15	11	9
Fluid produced (ha-m/100MW-y)	780	3,900	6,800
Fluid reinjected (ha-m/100MW-y)	60	3,200	6,800
Residual brine (ha-m/100MW-y)	0	3,100	6,800
Cooling water consumed (ha-m/100MW-y)	720	760	1,310
Heat in/Electrical energy out	6.5	9.1	11.0
Heat rejected/Electrical energy out	5.5	5.8	10.0
Heat in flash residue/Electrical energy out	0	2.3	0

Enthalpies relative to liquid water at 40°C.

ha-m = hectare-meter
(Meant in the sense of 10^7 kilograms of water; i.e., the water and steam flows are given in terms of their volumes as liquid water at about room temperature.)

Steam and double flash cycles assumed to be condensate cooled, and full cooling load assumed borne by evaporation. (This slightly overstates the cooling water needs, and slightly understates the reinjection volumes.)

*From Weres, Tsao and Wood (1977) based on data presented by Nathenson (1975).

pressured geothermal plants to inject waste hot water into the geothermal reservoir, making surface disposal necessary only under unusual circumstances. This may not be economically feasible for a geopressured system. The binary cycle requires a separate source of cooling water and could cause thermal pollution (U. S. Department of the Interior, 1976b).

Heat sources at the geothermal site produce only part of the heatload that such a facility may add to the biosphere. Any end use of the electrical energy produced by the power plant will also produce waste heat (second law of thermodynamics). The amount of heat at any one of these "end use" points might be small, but the cumulative total would be much greater. Production of such "end use" heat may result in substantial local effects. For example, an electric refrigerator may raise the temperature of a kitchen so that additional energy is demanded to run the air conditioner or the exhaust fan, etc. Such cumulative uses in urban areas may contribute to their dessication.

Thermal problems associated with various types of power plants currently in use have been well documented, and such problems of heat discharge will not be discussed in great detail because many available references may be located in the annotated bibliography accompanying this report (Appendix F). Heat affects the physical properties of water such as density, viscosity, vapor pressure and solubility of dissolved gases. Consequently, such processes as settling of particulate matter, stratification, circulation and evaporation can be influenced by changes in temperature. Because solubility of oxygen in water decreases as temperature increases, thermal pollution reduces the oxygen resource. Clark (1974) has stated the following areas of concern for thermal pollution in coastal environments:

(1) Heat affects the rate at which chemical reactions progress, and it can speed the formation of undesirable compounds or change dynamic equilibria. It affects biochemical reactions, and higher biochemical rates can result in a more rapid depletion of the oxygen resource.

(2) Physiological processes such as reproduction, development and metabolism are temperature dependent. The geographic ranges of many species of fishes and the species composition of communities are governed to a great extent by environmental temperature. Temperature anomalies also can block passage of anadromous fish, greatly reducing future populations.

(3) Thermal pollution affects other aquatic organisms such as plants, the benthos and bacterial populations. Increased temperatures

may reduce the number of species in a community and stimulate excessive populations of certain species to nuisance conditions.

Potential impacts of discharge of geothermal heat into the atmosphere and surface waters of Texas and Louisiana are of great concern. Greatest impacts would be on the aquatic ecological systems. Effects on terrestrial systems are not as well documented, possibly because of the subtle nature of these impacts. An obvious possible effect of thermal pollution is an immediate kill, but less obvious sublethal effects may pose greater risks because they can have far-reaching effects on entire populations. These types of effects include seasonal distribution patterns, growth effects, reproductive timing and success, metabolic regimes and so forth. Holland *et al.* (1971) found that mortality in Blue Crabs (*Callinectes sapidus*) was directly related to temperature above 30°C, and the upper incipient lethal temperature for juveniles was 33°C. Gallaway and Strawn (1975) found that fish diversity indices in a hot water discharge area of an electric generating station in Galveston Bay, Texas, declined above 35°C. Temperatures lower than lethal levels may result in stimulation of growth and reproduction in the cooling system and thermal plume of a power plant during the seasons when ambient water temperature is less than optimum, but growth, reproduction, and survival are reduced when the elevated temperatures become excessive. Additional problems may arise when organisms are utilizing the warm waters during the cold months and the effluent is shut down. The refuge may become a death trap under these circumstances (Lauer *et al.*, 1975).

Edwards (1969) states that temperature appears to be of primary importance in the seasonal distribution of Texas benthic marine algae, and Thorhaug (1976) found temperature to be a critical factor in the growth and survival of the seagrass community. Subtle effects of increased temperature may be expressed as reduced ability to cope with additional stresses. Wohlschlag *et al.* (1968) found that scope for routine activity declines at higher temperatures (near 30°C) for the Pinfish (*Lagodon rhomboides*). In this case, if the fish were presented with an additional stress such as an industrial effluent from which it could not escape, death might result.

If surface waters are used for a cooling system or for disposal of geothermal fluids, the effects of heat discharge will depend upon the location of the plant including the general location scenario and the particular site within the scenario. Local climatic modifications may result including increases in mean air temperatures and increases or decreases in precipitation and cloud cover (including fog). There is also the possibility of synergistic effects because other industrial or agricultural interests may be using the same water source: this might result in conflicts and possibly magnification and/or serious fluctuation of thermally related environmental problems.

Water vapor discharge

Once through running stream systems, continuous recirculation from cooling ponds, spray ponding, mechanical wet draft towers or non-draft evaporative towers may be used for condenser cooling of geothermal power stations. Each of these systems employs treatments or induces some chemical and physical effects on the cooling waters (see Phase I: Gustavson and McGraw, 1977). Chlorine may be added to prevent fouling of condensers by untreated natural waters. Chlorine is commonly used in about 90% of the power plants in the U.S. as an antifoulant agent (Thatcher et al., 1976). Additional algacides, biocides, and corrosion and scaling inhibitors are also added to recirculating cooling systems and these chemicals can become concentrated by evaporation in draft towers or holding ponds. In addition to the usual inorganic salts, the droplets may contain chromate ion added as a corrosion inhibitor and sodium pentachlorophenate added as a bacteriocide (Muehlberg and Shepard, 1975).

The droplets of cooling water entrained in the exhaust plume will ultimately result in the deposition of the salts dissolved in the cooling water on the surrounding land surface. This drift from mechanical draft cooling towers is a potential source of environmental problems. At the Geysers geothermal field in California, it has been demonstrated that boron drift particles falling on vegetation are the primary cause of leaf damage. On the Texas-Louisiana Coast, damage to rice and other agricultural crops and to natural flora could result. If geothermal steam condensate from high salinity geothermal fluids were used as cooling water, boron and other toxic materials could be present (Shinn, 1976). A 1,000 mW complex would evaporate some 113,600 to 132,600 cubic meters of water per day. This could have a significant impact on local climate depending on the rate of mixing and dispersal of the vapor (U.S. Department of the Interior, 1976b).

Drilling fluids and rock cuttings

For each well drilled (production or injection) a quantity of rock material equal to the volume of the hole drilled must be removed. Rock cuttings are disposed of by burial on site or in upland areas, although they are normally placed in a sump near the drill site for temporary storage. Cuttings from off-shore wells or wells located in wetlands must be returned to dry land for proper disposal. Such cuttings should produce few ecological problems if proper disposal techniques are utilized.

Drilling muds also present disposal problems. Mud sumps are normally constructed near the drill pad site for the temporary storage of these muds and possibly temporary storage of geothermal resource effluents produced during short tests. Because of the toxic nature of certain drill mud additives, sumps are normally subjected to permeability requirements (U.S. Department of the Interior, 1976b). Muds are usually very alkaline (pH up to 10) because of the addition of sodium hydroxide. They may be reused, but after extensive use lose their properties and must be disposed of. They are often left to dry in the mud sump, which is then graded over to an appropriate contour. Alternately, muds may be stored in tanks and later transported and disposed of at approved dump sites (U.S. Department of the Interior, 1976b).

Under ordinary operations, the vegetation and small animals of the area may be directly affected by toxic materials spread on the landscape if concentrations of toxins are high. Rain or flooding could compound impacts by moving toxic substances into surface waters. Aquatic organisms can be affected and possibly killed. Trees with deep roots may not be able to grow in soil covering shallow buried drilling wastes. Leaching of the toxic substances into deep groundwater may have effects at considerable distance from the source. Rigs used on water locations do not use sump pits. In these cases if the cuttings and waste muds do not contaminate the water they are dumped directly into it, otherwise the cuttings are collected in barges and hauled ashore for disposal (Rogers, 1963).

It appears that drilling fluids and rock cuttings will produce little impact upon the environment if state-of-the-art disposal techniques were employed. Proper management of drilling operations and enforcement of disposal regulations should mitigate the possibility of environmental alterations.

Sewage and refuse

During construction and normal operations of a geothermal facility refuse including human wastes and garbage will be generated (see Phase I: Gustavson and McGraw, 1977). Muehlberg and Shepard (1975) have estimated the required operating personnel for a hypothetical geothermal demonstration plant in Willacy County, Texas to be between 35 and 40 people. If a larger facility were constructed there would undoubtedly be increases in personnel requirements, and construction of any satellite industries would result in additional disposal problems. There are special ecological problems concerned with solid wastes (garbage and trash) in coastal areas. Most of these can be solved by locating disposal areas away from ecologically sensitive shore areas and by proper design and operation of disposal sites (Clark, 1974).

There are two major reasons for not utilizing vital areas (wetlands, tidelands, and drainageways) for disposal sites. Such areas are essential ecosystem components, and wastes deposited in tidally flushed areas have a high potential for gross pollution of coastal waters. It is equally unacceptable to dump wastes and refuse directly into estuarine or ocean waters. Coastal floodplain sites are not good dump locations because of probable pollution from nutrients and from chemicals which are toxic to aquatic life and which are carried into coastal waters by storm flooding, precipitation and land drainage. Copeland (1964) states that limited tidal range and exchange of water with the open Gulf results in the mixing of waste waters with the receiving bay waters to produce new regimes that lead to ecosystems hitherto unknown to science.

Eutrophication is the major problem associated with human waste disposal into open waters. Eutrophication is accompanied by dramatic changes in the composition of the aquatic community, with progressive deterioration of water quality, advent of algal blooms of obnoxious species, elimination of desirable (commercially important) fish and shellfish, and often anoxic conditions in the sediment and water. Algal blooms and oxygen problems associated with eutrophication usually occur in the warmer months of the year. These conditions can occur in both fresh and marine conditions. Craig and Day, (1976) have listed Microcystis spp., Anabaena spp., Anabaenopsis spp., and Spirulina spp. as the dominate freshwater blue-green algae. Brackish and saline waters are dominated by small coccoid algae such as Monodus spp., Nanochloris spp., and Stichoccus spp. Knudson and Belaire (1975) have considered the problems of oxygen depletion fish kills because of algal blooms in a sewage effluent area of Dickinson Bayou in Texas.

Recommended constraints for mitigation of sewage and refuse impacts include the following:

(1) Solid waste disposal sites should be located out of coastal floodplains, wetlands, tidelands, and water areas.

(2) In coastal watersheds, solid waste disposal sites should be located away from water drainage courses, well above the high ground water level, so as not to interfere with normal drainage patterns.

(3) Any wastes produced in offshore operations should be stored and transported to proper disposal sites on land.

Noncondensable gases

Noncondensable gas emissions can reach wildlife habitats near geothermal sites. Noncondensible gases that may be present in geopressured fluids include carbon dioxide (CO_2), ammonia (NH_3), methane (CH_4), and hydrogen sulfide (H_2S). Methane would be largely removed from such fluids by gas separators (Phase I: Gustavson and McGraw, 1977). Operating releases of other gases can be partially controlled (Andersen and Wallace, 1976). Latest control technology at the Geysers Field has resulted in 92% abatement of H_2S emissions during normal operation of power plant No. 11 (Weres, Tsao and Wood, 1977).

Other noncondensible gases which have been found in normal pressured geothermal fluids from other geographic regions such as carbon monoxide (CO), hydrogen flouride (HF), mercury compounds (Hg) and radon (Rn) are not expected to occur in significant quantities in geopressured fluids from sedimentary geological formations. See Tables 9 and 10.

Although there are substantial data on the effects of carbon dioxide, ammonia, methane and hydrogen sulfide on human health (Weres, Tsao and Wood, 1977), there is a lack of knowledge for predicting effects of releases of these gases upon components of ecosystems. Of the noncondensible gaseous pollutants in geothermal steam, hydrogen sulfide is most often objected to by humans. It can be detected by the human nose in extremely small concentrations (0.002 ppm) (Andersen and Wallace, 1976). These authors note:

> "The rotten egg odor of hydrogen sulfide and odors of other gases diminish property value for residential and some industrial development and may make farming operations unpleasant. Hydrogen sulfide (H_2S) gas causes rapid corrosion of copper, steel, silver, cadmium, and concrete (Finney, Miller, and Mills, 1972)."

It appears that many geopressured waters contain less H_2S than the normal pressured geothermal waters of the Geysers field.

The effects of H_2S on diverse members of various trophic levels are not known. H_2S is slowly oxidized to SO_2 and may ultimately be converted to H_2SO_4. These substances can be directly toxic to animals in sufficient concentrations (Waldbott, 1973). Under atmospheric inversions, such contaminants from a steam release source could reach undesirable levels near the area of operations (U.S. Department of the Interior, 1976b). Thompson (1976) and

Weres, Tsao and Wood (1977) have surveyed and evaluated the existing literature on the atmospheric behaviour of H_2S and its effects on vegetation and human health.

"Concentrations of certain gases which, when considered separately, may be too low to cause apparent vegetation damage, may in combination be injurious because of interactions of the gases" (Andersen and Wallace, 1976). The resultant damage may be expressed as growth suppression, dwarfing, and early maturation (Feder, 1973). "Crops requiring pollination may not be serviced if wild and domestic bees are killed or if aromas repel the bees... If H_2S were released into areas having photochemical smog and the sulfide were oxidized to sulfur dioxide (SO_2), a synergistic injury to crops could occur" (Andersen and Wallace, 1976; Calif. Div. of Oil and Gas, 1974, p. 34; Menser and Heggestad, 1966). The latter might not be a problem in most rural areas of Texas, but the synergism might have serious effects in such highly populated areas as greater Houston. That city already has a major photochemical smog problem. "Synergistic effects have been documented for various pollutants, but not for the combination of factors from geothermal operations" (Andersen and Wallace, 1976); see also Menser and Heggestad (1966), Heck (1968), and Hindawi (1967, 1968).

Considerable research is being done on the effects of air pollution related to geothermal developments in California's Imperial Valley by investigators of the Lawrence Livermore Laboratory of the University of California at Livermore. They are ERDA's principal geothermal environmental task force.

It appears that currently insufficient knowledge of ecosystem effects from noncondensable gases will require that steam and gases venting to the atmosphere at a geopressured site be analyzed for their constituents and appropriate control methods be applied. Control could include removal of H_2S by scrubbing techniques.

SECONDARY EFFECTS

Energy conversion industries produce effects other than those directly associated with energy conversion at the industrial site. The kinds and magnitudes of such effects may vary considerably. One major factor is the role of the output of a geothermal plant in the local or regional energy budget. If this output meets demands which would otherwise be met by other energy technologies, the output of such a plant may have few secondary negative effects such as those related to land use. If the geothermal energy output adds to the energy budget amounts greater than those which would be available from alternative sources, such output contributes to increases in several kinds of secondary effects.

Effects of increased energy availability

Increased energy availability may lead to population growth, industrial growth, and urban or suburban growth. Several ecological land use problems often result from the above energy-related growth effects. These include a decrease in wildlife habitat, decrease in agricultural land, increased air, water, noise and solid waste pollution, increased erosion, increased flooding and decreased availability of fresh water (Christiansen and Clack, 1976; Clark, 1974; Hardin, 1972; Southwick, 1976).

Not all of the changes which result from the above types of growth are negative, at least for some segments of the human population. For the land owner, the value of his property increases. For the potential homeowner, his costs increase by the same change. Economic values of commercial products usually increase, which benefits businessmen, but results in increased costs for consumers. Operational costs normally increase for everyone. Construction costs increase, but these benefit some industries. Restoration costs of negatively impacted lands increase (Gosselink, Odum and Pope, 1974). Secondary costs such as medical care often increase. Social costs or values may increase or decrease. Crime normally increases but so does availability of positive social activities. Aesthetic costs or values may increase or decrease depending not only on the nature of a particular change but upon the point of view of one who perceives it.

Urbanization

Construction of a geothermal facility on the Gulf Coast would undoubtedly result in increases in human populations in the vicinity of the plant including at least those persons directly involved in the plant operations and their families. Additional increases may be related to associated secondary industries.

The process of urbanization in coastal areas involves a complex of potential ecological disturbances to coastal waters both from construction activity and from human occupancy and activity. Such disturbances are intensified by increased housing density, close proximity to the water, extensive alteration of the shorescape and the ecological sensitivity of the ecosystem (Clark, 1974). Coastal residential communities require roads, marinas, storm drain systems, parking lots, waste treatment facilities and so forth. Each of these has the potential to become a major source of disturbance resulting in pollution of coastal waters, interference of water flows in the watershed or in coastal water basins, and degradation of vital ecological systems.

Residential construction pollutes coastal waters largely through erosion that results from land clearing and site preparation (see facility construction and maintenance section above). Waterflows are altered by blocking shoreland drainageways or regrading the land surface, creating impervious surfaces and installation of storm drain systems, shortcircuiting natural drainage flows with access canals, causing saltwater intrusion of ground water by canals, and by increasing the tidal prism by canal excavation and navigation channel deepening in adjoining water basins. Degradation of vital areas may result directly from on-site construction or from alterations in normal water and nutrient flow patterns to the areas of concern.

Urban growth is often associated with chemical pollution of air, water, and soils. This may result from a variety of activities including products of sewage systems, energy conversion systems, transportation systems, biological processes, industrial practices, medical practices and modification of natural biological communities including use of biocides.

Deer habitats and urban subdivisions are incompatible land uses. When construction of a subdivision begins, the deer population in the area declines. Not only do houses, streets, and utilities replace their habitats, but automobiles and unleashed dogs are responsible for the deaths of thousands of deer every year. These detrimental effects extend well beyond residential neighborhoods. Industry can have an indirect impact on deer and their habitats by stimulating land use changes in the vicinity of industrial locations. When new industry encourages residential growth, sites should be chosen with consideration for potential damage to deer and their habitat (Blevins and Novak, 1975).

When considering the possible ecological effects of urbanization, existing and potential urban-industrial, extractive and agricultural contaminants should be identified and assessed in terms of additional environmental alterations (Coastal Bend Regional Planning Commission, 1971). Also to be considered are increased demands on freshwater supplies, which, in certain areas, may already be scarce.

Secondary industries

Several secondary industries might be closely associated with a geopressured electrical producing facility. This would almost certainly include the production of methane from geothermal brine in order to make the geothermal project economical. Heat from spent geothermal fluids may have potential uses for industries that can utilize low-grade heat in processing; (Underhill et al., 1976). Such industries include paper and pulp processing, mariculture, electrical cogeneration, greenhouse agriculture, and desalinization plants, but such industries probably cannot use the brines except as a heat source. Hornburg (1975) concluded that utilization of thermal energy from the geoenergy fluid in pulp and paper mills and new sugar refineries is technically sound and economically feasible, provided that the other energy in the fluid (natural gas and pressure) is recovered concurrently. Bishop (1975) has considered the use of geothermal water for agricultural purposes and Roberts (1975) has investigated fish culture utilization of geothermal energy. Any such facilities must be located near the geothermal plant because of the loss of heat that would occur in transporting these fluids.

Mariculture is a possible alternative use of geopressured resources. Low-grade heat from the effluent brines might be utilized as part of temperature control technology of mariculture ponds. It does not seem likely, however, that a significant fraction of the effluent would be needed for this purpose in the climate of this region. Furthermore, because of the very different chemical composition of geothermal brines from that of seawater, it is unlikely that marine organisms could be propagated in such fluids without considerable modification of their composition. In addition to differences in chemical composition of brines as they emerge from wellheads, there would be additional differences of waste effluents because of possible presence of corrosion products, corrosion inhibitors and biocides.

The result of secondary utilization of spent fluids could be an industrial complex located in a concentrated zone around the geothermal facility. The ecological problems associated with this sort of complex would be similar to those already discussed under construction and operation of the geothermal facility, with some additional problems unique to each industry. Therefore, any consideration of the effects of a geopressured production facility must consider not only those of fluid production and its electrical generating process, but also those of possible associated secondary industries and related urban growth (see Clark, 1974).

ADDITIONAL ENVIRONMENTAL CONCERNS

Noise

It has been suggested that noise from exploitation of geothermal resources may adversely affect wildlife in various ways (Shinn, 1976). If a secondary working fluid (binary) system is utilized no portion of the geothermal fluid will be released to the atmosphere. A flashed steam process would release pressure to separate the steam resulting in the propagation of noise. The separation strategy will determine whether the noise field is dispersed or centralized at the power plant. During normal operations of a power plant and associated wells, noise sources could include pipelines, gas separators, the turbine building, and the cooling tower facility.

Temporary noise level increases will result from the construction of each drill site and from well drilling. Noise levels from such operations of 80 to 90 dBA at the well site can be expected (Neilson et al., 1976). Ambient noise levels for an operational geopressured-geothermal field would probably be similar to those of a normal pressured hydrothermal-geothermal field, in the range of 40 dBA (Neilson et al., 1976). This is not substantially different from natural noise levels along the Gulf Coast (Federal Energy Administration, 1976). If it proves necessary to release geothermal fluids to holding ponds or as steam, noise levels could increase temporarily to substantial levels of 90 - 100 dBA at 15.2 meters from the source (Phase I: Gustavson and McGraw, 1977). Table 18 compares some familiar sounds with those produced by a geothermal development. Noise impact on wildlife is relatively unknown (U.S. Department of the Interior, 1976b). Impacts on wildlife per se may be minimal because of the relatively low intensity and steady continuous nature of most operating noise emissions. However, intermittent human activity and vehicular traffic associated with construction and maintenance of wells, roads, and pipelines in prime wildlife habitat may pose a greater problem, particularly to some species (Shinn, 1976).

It has been difficult to separate the effects of noise from other environmental changes produced by geothermal industrial activities (Leitner, personal communication). With regard to small mammals, Leitner has found that species different from those occupying undisturbed habitats occupy industrially disturbed sites such as pipeline rights of way. Thus species composition may change and some species may become more abundant, others less numerous. Very intense noise (up to 126 dBA at 7.7 m distance) in the Geysers field may negatively impact songbirds (Leitner, personal communication). Such noise levels should not occur with geopressured operations. Neither domestic cattle nor deer in the Geysers field appear to be permanently affected by noise emissions.

Geothermal noises might result in alarm and dispersal of animals at critical stages of their life cycles. Waterfowl and shorebirds may be particularly susceptible to disruption by these noises. This may not be a serious biological problem if reproduction and survival are not seriously jeopardized. It may present greater problems in terms of recreational usage of the resource. The problem of noise disturbance effects accompanying exploitation of geothermal resources in or adjacent to wildlife habitats appears to be a land use conflict (Shinn, 1976).

Table 18. Comparison with other familiar sound levels of noise produced during geothermal resource development.*

Geothermal Noise	Level (dBA)	Distance (meters)	Comparative Levels
	100	16.3	Unmuffled diesel truck
Drilling operation	90	15.2	
	75		Street corner in a large city (average)
Ambient noise level for an operational geopressured geothermal field (California)	40		Residential area at night (average)

*Modified from U.S. Department of the Interior, 1976; Weres, Tsao, and Wood, 1977; and Gustavson and McGraw, 1977, Phase I of this report.

Subsidence

Development of the geothermal resource requires that large quantities of fluids be removed from the subsurface for utilization and disposal. Fluid removal from geopressured formations could result in a series of geological phenomena, the end result of which would be subsidence of the land surface.

Subsidence may occur while the elevation of the groundwater table remains unchanged. This would result in a relative rise in the water table. If the root systems of surface vegetation are above the water table, such changes in ground-water level can also produce changes in plant communities. Subsidence in or near coastal wetlands could result in significant environmental impacts because slight changes in land elevation lead to extensive lateral shifts in both salinity and wetland vegetation zones. Fault planes, in part at least, may control or limit subsidence (Gustavson and Kreitler, 1976). Natural and fluid extraction-related subsidence is already occurring in many areas of the Texas and Louisiana coasts. Although recent fault movement has been documented on the Gulf Coast Plains (Kreitler, 1976), it is not a seismically active area. Faulting of geological structures associated with subsidence has also been investigated in Texas by Foin (1976). Such faulting has caused structural damage to pipelines, roads and buildings.

Subsidence could be a serious problem along the coastal plains of upper Texas and Louisiana because extensive irrigation systems and complex natural drainage patterns in these areas would be subjected to disruption by minor slope changes. Resultant effects on natural or man made levees could alter the normal pattern of saltwater intrusion into coastal marshes and estuaries where nursery areas may become unsuitable for species that are dependent upon freshwater input. Morgan (1972) has considered the impact of subsidence and erosion on Louisiana coastal marshes and estuaries. Muehlberg and Shepard (1975) estimate that the delayed effect of surface subsidence for a geopressured-geothermal facility in Willacy County, Texas, might ultimately approximate 3.05 meters over an area of about 128 square kilometers. It is difficult to predict the magnitude of such subsidence for a variety of reasons. According to various predictive models, the amount of subsidence which might result could range from one foot to 100 feet and affect an area of 50 square miles (Gustavson and Kreitler, 1976).

UNUSUAL HAZARDS

Large scale spills

Large scale spills of geothermal brines should not occur if proper technology and management techniques are utilized, but such spills are possible. Spills have occurred in the past at other geothermal sites and in oil and gas operations (see Appendix E). The phases of geothermal exploitation during which large quantities of brines may accidentally spill include the drilling operation (blowout), during normal maintenance procedures at the producing well, as a break in a pipeline bringing brines to the production facility, or because of a failure of the injection system and emergency holding facilities.

Blowouts may occur during the drilling of a well, but they can also happen during normal well maintenance at any time (see Phase I of this report.) Current oil and gas production operations in the Texas-Louisiana area are drilling into the geopressured zone. Expertise and technology is available to cope with problems associated with blowouts at geopressured wells (Stuart, 1970). Blowout prevention methods can fail; therefore Muelhberg and Shepard (1975) have suggested the construction of one meter high containment levees surrounding the entire plant area, including all wellheads. Spills occurring in aquatic environments (scenarios 2 and 3) would be difficult to contain, and the resulting impacts are difficult to predict at our current level of knowledge.

In the Geyser's Field of California, two of 160 steam wells drilled have blown out. One of these--Thermal No. 4--blew out in 1958, and efforts to control it have not been successful. This particular blowout was caused by inadequate casing. A blowout of this type is very unlikely today with proper utilization of available technology. This blowout produces large quantities of gases but relatively little liquid runoff. Much greater volumes of liquid might be involved with a blownout geopressured brine well (Weres, Tsao and Wood, 1977).

Pipeline breaks could produce severe large scale spills depending on the location of the rupture and the time required to locate and remedy the problem area. Breaks occurring on land would be easily recognized if the line were on the surface. Breaks occurring in buried lines would probably be indicated by losses of pressure, but may present special problems if they go undetected. The major concern in this case is leakage of brines into shallow freshwater aquifers. Muehlberg and Shepard (1975) indicate that such leakage, possibly resulting from corrosion of the pipe wall or outright rupture, is relatively unlikely. Surface spills could result in elimination of vegetation in the area of the spill and contamination of surface waters in the drainage basin (Figure 28). Breaks occurring offshore may produce problems as yet unpredictable, especially if the spill is undetected for a period of time.

Unusual climatic conditions

The coastal areas of Texas and Louisiana are periodically subjected to hurricanes and torrential rains. Wind damage from storms should produce few problems because construction of any power generation facility in these areas would utilize state-of-the-art technology to prevent such damage. Unusually large amounts of rainfall and associated flooding could produce severe problems with earthen holding ponds, buried pipelines, pipelines crossing wetlands, and the possible widespread distribution of geothermal effluents to inundated areas. The effects of escape of geothermal brine constituents may be mitigated to a great extent by the dilution of concentrated brines during such conditions. For a discussion of hurricanes on the Texas Coast and their effects on the various components of coastal physiography see Hayes (1967), Bureau of Economic Geology (1970) and Brown _et al._ (1974).

Another unusual climatic event is an atmospheric inversion. Such circumstances might result in concentrations of gaseous pollutants in the lower atmosphere (Weres, Tsao and Wood, 1977).

There is a considerable literature on the potential effect of gaseous emissions on global climate which has been termed the 'Greenhouse Effect'. This process originally pertained to effects of carbon dioxide on atmospheric temperature. It is now predicted that other substances such as methane and ammonia could also have similar effects and result in increased temperatures world wide (Wang _et al._, 1976). One or two 25 megawatt geopressured-geothermal electric plants would not add significantly to the atmospheric concentrations of these substances, but they would add an increment to amounts which are produced by other processes. Of particular concern is the increased load of carbon dioxide from non-biological sources, particularly via combustion of hydrocarbons. If geopressured reservoirs were extensively exploited for either heat and/or natural gas, the amounts of carbon dioxide, ammonia and methane added to the atmosphere from such activities could be substantial.

RESTORATION OF IMPACTED HABITATS

Coastal ecosystems contain some of the most productive biological communities found on earth. Conversion rates of solar energy into biochemical energy in these areas are enormous. The life of a geopressured-geothermal field has been predicted to be approximately 20-30 years. Therefore, an assessment of possible impacts upon environments to be affected by exploitation of the geothermal resource must consider the fate of the site after the resource has been exhausted. Planning for such industrial sites must be carried out with consideration for restoration of impacted habitats, especially in areas where original biological productivity was high.

Agricultural lands

Only accidents should release geopressured brines to surface ecosystems. Such spills might result in contamination of a maximum of 4-8 hectares (10-20 acres) if the geothermal field is effectively contained with dikes (Gustavson, personal communication). For restoration of agricultural lands where brine spills occur to be effective, it will be necessary to initiate studies early in the use of a geothermal site on the fate of brines within the plant-soil-water system. These should include studies of brine movement through the soils, chemical and physical effects on soils, influence of high salt environment on transition and heavy metal availability and chemical speciation, and the tracing of brine components through the water/soil/plant system. The physical characteristics such as hydraulic conductivity of the brine should be determined, and efforts to assess brine movements in the hydrologic region under various hypothetical leak conditions should be made (Shinn, 1976). Such research will allow for determination of proper leaching stages, fertilization, irrigation, and selection of agricultural species for revegetation. The chemical makeup and volume of each leaching stage and the number of stages must be determined for representative site specific soils, by a series of experimental trials.

Fish and wildlife habitats

The initial effort in restoration of fish and wildlife habitats will be in reestablishing vegetation, provide wildlife food and cover, and ensure soil stability and natural drainage patterns. After removal of structures (wells, drilling pads, buildings, etc.) and potentially toxic materials (evaporated brines and drilling mud residues), the terrain should be restored to natural contours whenever feasible. Natural plant succession on certain soils may require 50 to 100 years or more to return the area to its former undisturbed state (U.S. Department of the Interior, 1976b). Transplantation of seedlings, fertilization and watering should be considered to accelerate reestablishment of the vegetation pattern.

Wildlife should return to the area as vegetation becomes established. Aquatic organisms (plants and animals) should return to impacted areas when the various factors which were responsible for impacts are removed. If persistent impact producing components are identified which prevent return to natural ecosystem conditions, then these materials should be removed to approved disposal sites. Alternatives to reestablishing natural systems should be considered and may require consultation with local planning agencies. New beneficial uses for the site may include agriculture, recreation, water storage, etc., which with proper planning and management, may offer an opportunity for reestablishing native animal species and for increasing area productivity. Other options include new industrial complexes and urbanization of the abandoned site.

Restoration costs are of major concern to landowners. California law requires that oil companies post bonds guaranteeing the restoration of impacted sites at the time that permits are issued for oil field operations. It is unclear whether this is required by rules of the Railroad Commission or the Water Resources Department in Texas.

MANAGEMENT AND ITS PROBLEMS FROM AN ECOLOGICAL VIEWPOINT

There are potential sociocultural problems, not necessarily unique to geopressured activities, which could interfere with effective ecological management of geopressured industrial facilities. These include educational, managerial, legal and political problems. Ecological education problems are not limited to energy industries, but partially result from an historical lack of emphasis on environmental education in the backgrounds of personnel associated with industries. An oil field or geopressured resource worker may not be aware that his welfare is affected by what happens to wildlife in an area. This may result in his feeling little responsibility for his actions which affect the environment. Such problems may not be limited to blue collar workers, and may include personnel managers, engineers, etc. who may perceive the function of the industrial operation only in terms of its ability to produce a given level of economic profit within the shortest period of time. Even some at the highest levels of industry may have little concern for long-range long-term environmental costs of their operations, particularly if such might be incurred by future generations.

Intimately related to the above issues are managerial problems which may result in lack of effective maintenance of industrial facilities. For example, it is apparently the policy of oil companies to prevent releases of pollutants to the surrounding environment, but some small scale releases may be overlooked. For example, oil well pumping structures should have properly maintained traps constructed beneath them to collect any oil which may leak from the pumping mechanism. Figure 29 shows a clean effectively managed oil well with no leaks on the Aransas National Wildlife refuge. Figure 30 is but one of many leaky wells in an east Texas field. In the latter, one can see the effects of oil on the ground which has leaked around the well pumping rod. One leaky well may have a small environmental impact, but lack of environmental awareness or poor industrial management may result in many small leaks over a large area, the combined effects of which may result in substantial impact.

The variety of management practices applied to fluid storage pits also indicates the range in level of concern for the environment within the oil industry. Shallow storage pits are generally disallowed according to Texas Railroad Commission regulations. Any pits or sumps are supposed to be maintained in a way that they do not leak or overflow (Gustavson and Kreitler, 1976). Figure 31 shows an effectively managed pit for treatment of brine on the Delta National Wildlife refuge, Plaquemines Parish, Louisiana. Figure 32 shows a small pit receiving brine in the Saratoga Oil Field in east Texas. In addition to brine, there is a thick layer of hydrocarbons on the surface of the pool. This structure has recently overflowed during heavy rains onto the surrounding land which drains into part of the Lance Rosier unit of Big Thicket National Preserve, Hardin County, Texas.

Effectively managed oil storage tanks and pipelines can be seen in Figure 33 on the Aransas National Wildlife refuge. Figure 34 shows an array of apparently unplanned surface polyethylene pipelines being used for the transport of brines in the Saratoga Oil Field of East Texas. If the current range of oil field environmental management policies is indicative of the range of policies that could be applied to geopressured-geothermal resources, then there is a strong need to increase environmental awareness among industrial workers and management.

The Texas Department of Water Resources and the Texas Railroad Commission have the authority to sample pollution in oil fields and have the power to force compliance to regulations proscribing pollution. If extensive development of the geopressured-geothermal resources of Texas occurs then substantial budget increases for regulatory agencies may be required to support their increased regulatory responsibilities.

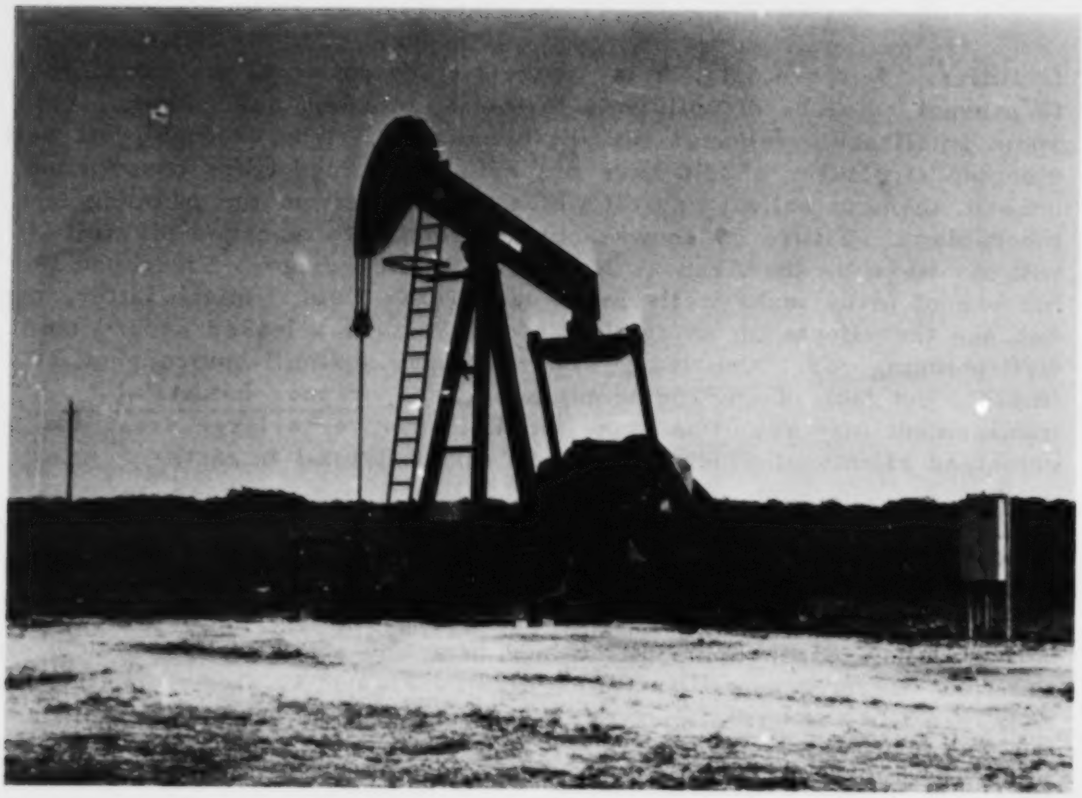

Figure 29. A "clean" effectively managed oil well on the Aransas National Wildlife Refuge. Continental Oil Co. lease. March, 1977. Photograph by W. L. Longley, R. P. C., Inc., Austin, Texas.

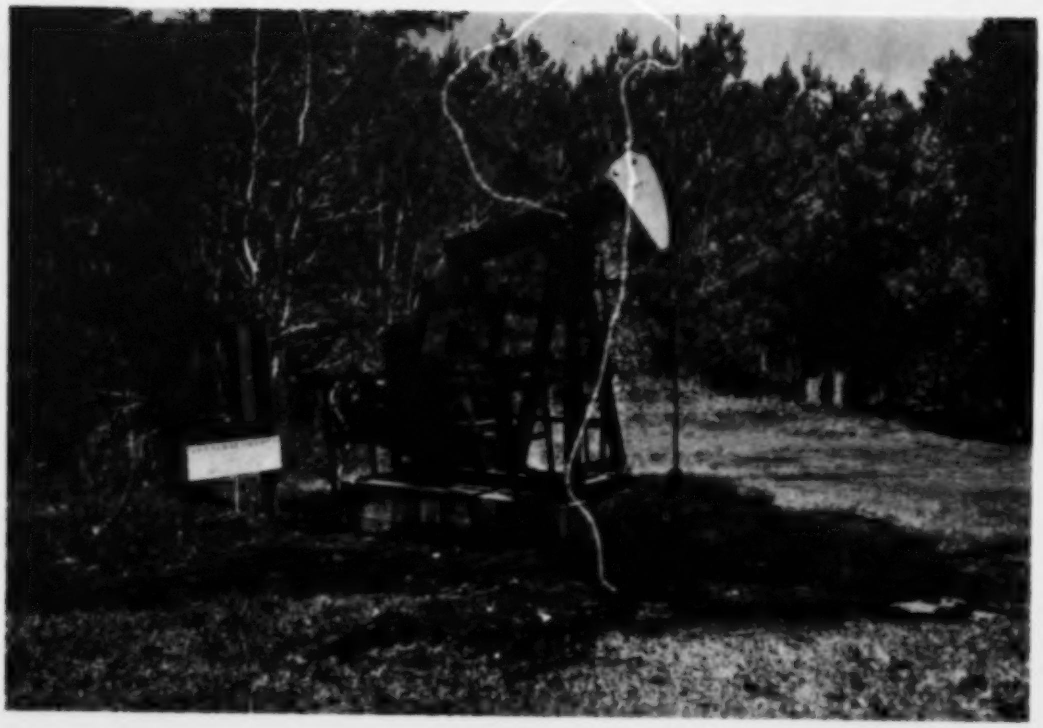

Figure 30. An oil production well in the Saratoga field of east Texas. March 29, 1977. Photography by M. Tandy.

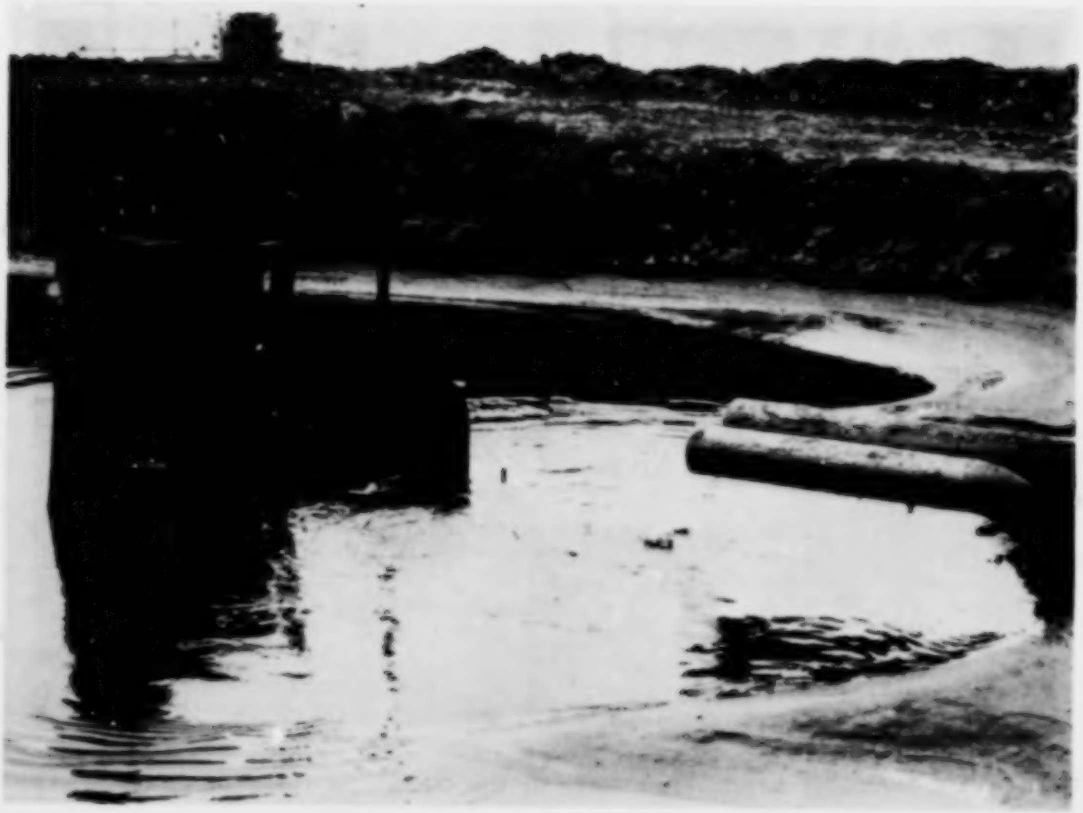

Figure 31. A properly managed pit for treatment of brine on the Delta National Wildlife Refuge, Plaquemines Parish, Louisiana. Chevron Oil Co. lease. March, 1977. Photograph by W. L. Longley, R. P. C., Inc., Austin, Texas.

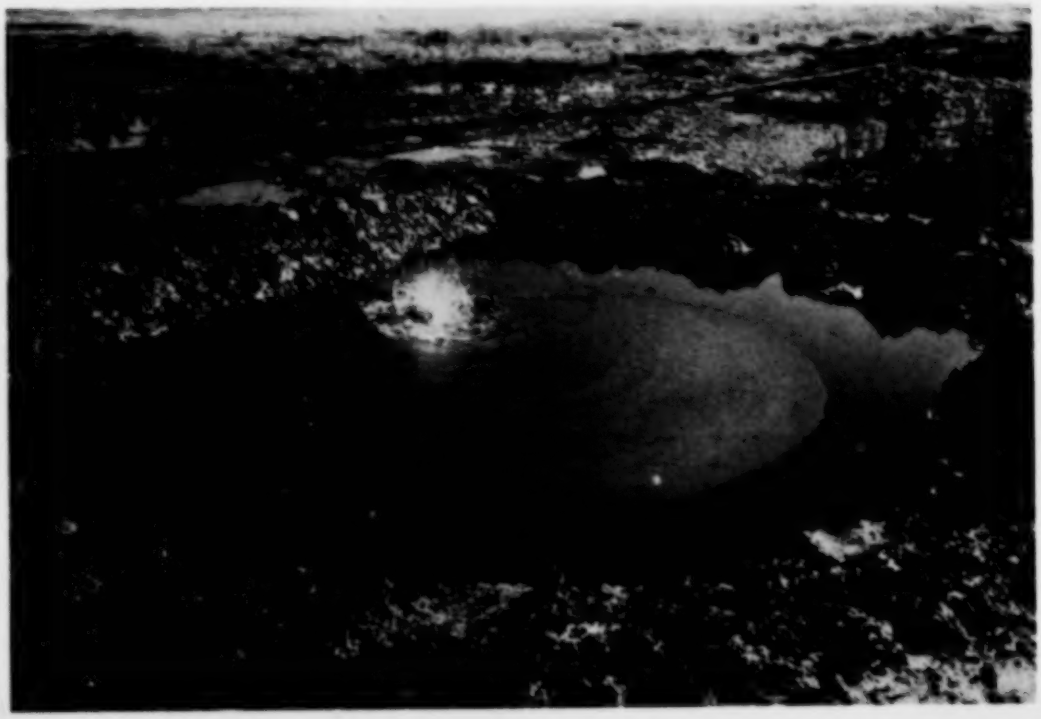

Figure 32. A small pit receiving brine and hydrocarbons. Saratoga Oil Field, Hardin County, Texas, March 28, 1977. Photograph by M. Tandy.

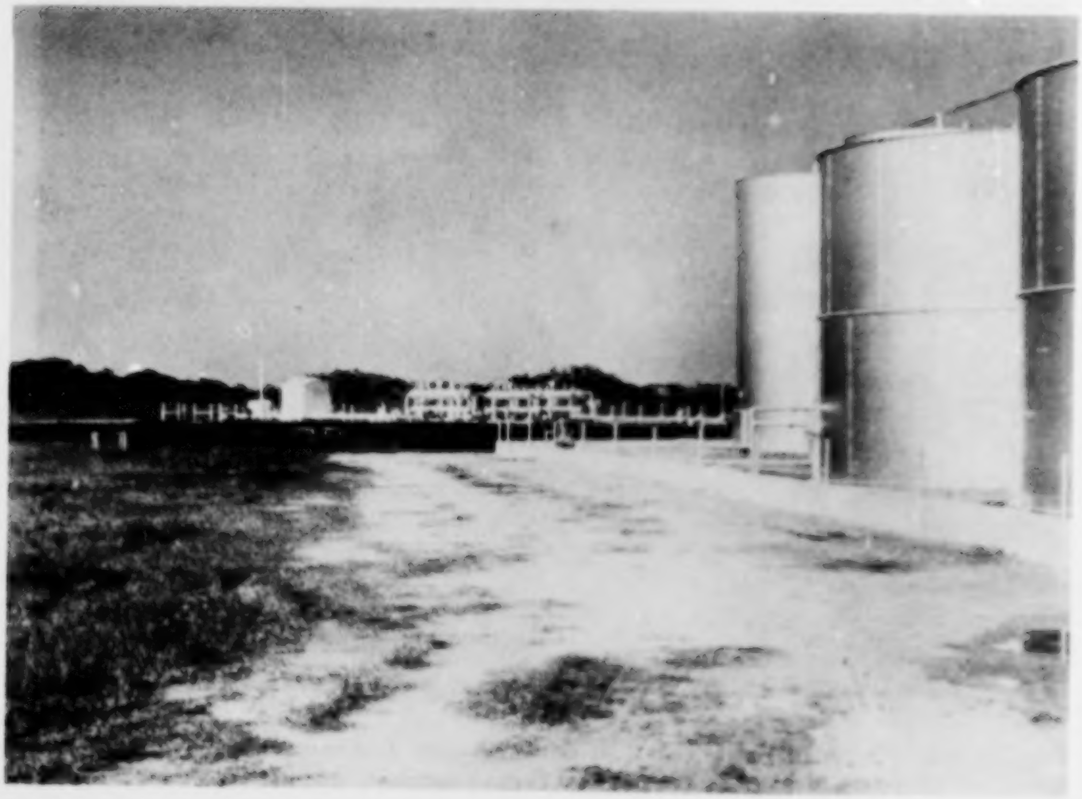

Figure 33. An effectively managed complex of an oil tank battery, pipelines, oil-gas-brine separators and a brine treatment pond on the Aransas National Wildlife Refuge. The brine pond is concrete lined (especially important because of the locally very porous soil) and is covered to prevent entry of wildlife. Continental Oil Co. lease. March, 1977. Photograph by W. L. Longley, R. P. C., Inc., Austin, Texas.

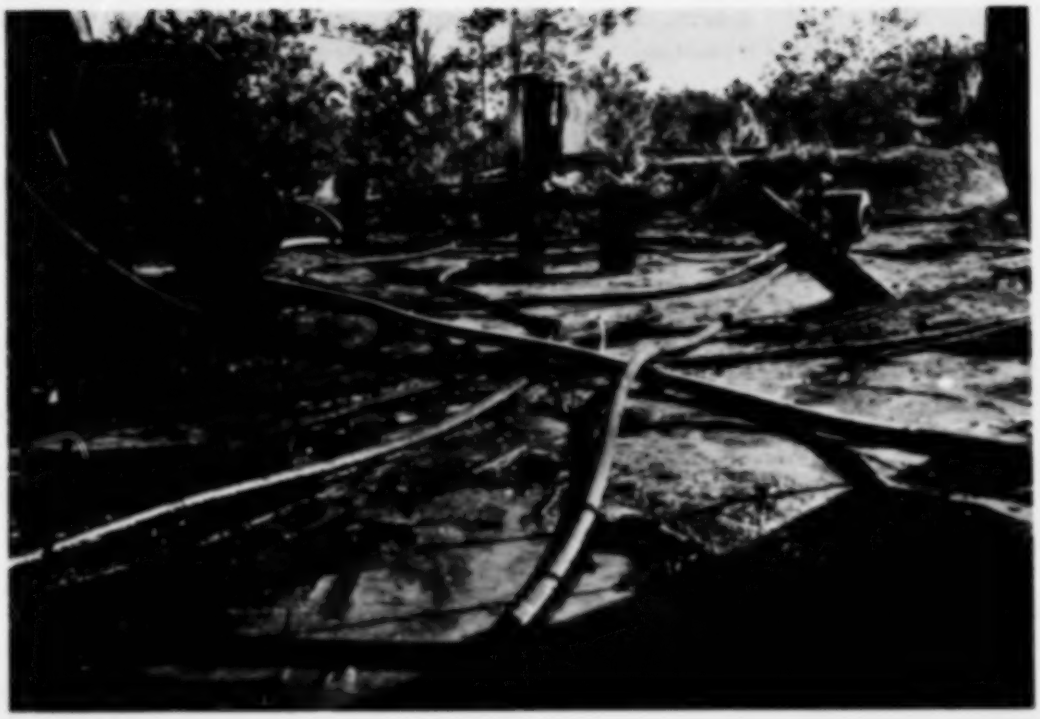

Figure 34. An array of apparently unplanned surface polyethylene pipelines and old brine ponds. Saratoga Oil Field, Hardin County, Texas. March, 1977. Photograph by M. Tandy.

Mr. "Red" Adair, the well-known expert on control of oil well blowouts, recently testified to the U.S. Congress that almost all oil field disasters result not from technological failures but from human ones. This applies to the recent vast spill of oil from a well blowout in the North Sea. Among other management and construction errors on the well, one of its blowout prevention valves was mounted upside-down making it inoperative. It is then a reasonable assumption that if a disaster occurs in a geothermal field it will probably result from human error rather than a technological failure.

Adair suggested that further legal requirements may not produce a solution for such. He suggested that insurance companies require oil companies to effectively train their personnel so that such errors can be avoided (CBS News, 1977). Such a procedure would seem appropriate for geothermal operations. And training should include not only construction and engineering topics but also ecological education to bring awareness of the importance of effective environmental engineering.

Many legal problems may be associated with geothermal development. Some of these have been addressed by Andersen and Wallace (1976) and Elmer and Rogers (1976). It should be noted that unlike California, Texas does not require environmental impact statements to be filed by exploiters of energy resources. This may change if procedures being planned by the Texas Coastal Management Program for analysis of permit applications are implemented (General Land Office of Texas, 1976). Impact statements may be required via regulations of the National Environmental Policy Act if federal funds are involved.

Although Texas statutes require that industrial operations not produce certain types of pollution or practice other activities that can be damaging to natural resources, many such regulations provide for exceptions (Gustavson and Kreitler, 1976). We do not know the frequencies of such exceptions.

Initial exploratory and test facility work toward exploiting geopressured-geothermal energy is being federally funded. This financing requires that U.S. Environmental Protection Agency regulations are satisfied. This should set a precedent for all forthcoming exploitation. Hopefully this will result in environmentally sound planning and implementation in the future.

Related to educational, managerial, and legal problems are environmental political problems which are serious in Louisiana and Texas. It is not surprising that the politics of these states are heavily influenced by energy industries which form a major part of their economies. This means that concerns, such as environmental ones which may be in the interest of the general public but which are counter to the short range economic goals of commercial interests, must be given effective attention at the state level. It may be appropriate for the federal government to be a contributor to geopressured exploration and experimentation in order that federal environmental standards may be applied to such activities.

Priority recommendations

The most important ecological concerns associated with exploitation of geopressured resources include effective industrial management to prevent environmental damage, release of toxic substances in large scale spills of hot brine, long term concentrating processes of toxic substances which may accumulate over time, accidents including technological failures, competition for scarce water resources, and costs of restoration of geothermal fields after their useful life for electrical energy production. General lack of knowledge concerning the nature of the geothermal fluids and potential long-term impacts of injection of spent brines on ecosystems indicate that measures need be taken to protect ecological integrity that will also provide some of the badly needed information. Cairns (1977) has suggested the following interim measures to accomplish this end:

(1) Carry out an environmental risk analysis before initiating any new construction.

(2) Develop a regional plan designed to maximize use of "tough" ecosystems and protect the more vulnerable ecosystems.

(3) Require an ecological baseline study at least before and after all new construction, and so on.

(4) Require bioassays for all potentially hazardous materials.

(5) Require biological monitoring of all high risk point source discharges.

OVERVIEW OF ECOLOGICAL CONSIDERATIONS

Because of the number and nature of potential ecological problems associated with geopressured-geothermal energy exploitation, such projects should not be pursued in especially sensitive ecological environments including the habitats of endangered or otherwise valuable species. Sites should be avoided which could result in damage to off-site habitats that are influenced by on-site processes.

Siting problems are the most immediate area of concern for geothermal exploitation because the power plant must be located near the geothermal reservoir. This constrains the possibility of site selection to minimize environmental damage for extraction scenarios. The initial site selection becomes extremely important, leaving only technological and managerial techniques to mitigate possible impacts (Andersen and Wallace, 1976). Therefore it appears that the most crucial question from an ecological viewpoint will be decisions on whether a site is to be exploited.

Areas to avoid

Areas which should be avoided as geopressured-geothermal industrial sites include valuable fish and wildlife habitats as previously noted. Also to be avoided are valuable biological economic resources which might be damaged such as especially productive croplands and portions of the estuarine system that are important as nurseries for fishery resources. Care should be taken to avoid areas where groundwater supplies might be damaged, especially where water supplies are critical. Prairie sites should be preferred to forest sites or deserts because restoration of vegetation of forested or desert sites by natural ecological succession requires a much longer time than for prairie.

Onshore versus offshore siting

It appears that in all three extraction siting scenarios at least some portion (generating and disposal facilities) of the facility will be located on land. With this in mind, it becomes evident that Scenarios 2 and 3 may include considerable transportation problems to bring the geothermal fluids to the generating facility. Of the wetland and marine habitats which might be impacted, current knowledge indicates that geothermal industrial activities in open Gulf waters may be preferable if technology can be developed for exploitation in this area. Freshwater, estuarine and marsh systems are much more sensitive than the open Gulf to the types of stresses that may be produced by geothermal exploitation in the coastal zone.

Conversion system alternatives

Of the various extractive conversion systems proposed, including flashed steam, a binary cycle, or total flow systems, the total flow system is the most ecologically desirable because it does not require an outside source of water for cooling. The binary system is preferable to the flashed steam method because the binary system could accomplish much of its cooling, although not all of it in the climate of the coastal zone, by air cooled towers. This system has the added benefit of not passing noncondensable gases to the atmosphere. Cogenerative systems should be considered to utilize the low grade waste heat that would be produced as an end product of the extractive facility.

Fluid composition considerations

There are great differences between the composition of geothermal brines and seawater, not only in the ions present, but also in the relative concentrations of these ions. There may be toxic substances present in the geothermal brines or in the cooling waters and these substances should not be released to terrestrial or aquatic environments. Deep injection appears to be the only ecologically acceptable disposal method for such fluids and there may be as yet unforeseen risks associated with this method.

Planning

Facilities using geothermal heat must be located near the production field. Careful and comprehensive planning should be initiated to determine whether the field and any and all associated structures, including industries and urban developments, would be compatible with other uses of the site and surrounding areas. Consideration must be included for such resources as wildlife and agriculture.

RESEARCH RECOMMENDATIONS

The nature of the geothermal resource in the Gulf Coastal zone, as defined in this report, is relatively unknown. In addition, lack of knowledge on the impacts that might occur from the development of such a resource has led to the following recommendations for research associated with planning, construction, operation and restoration of any proposed geothermal site along the Texas-Louisiana coasts:

(1) Site specific baseline investigations should be conducted which include habitat mapping. Down-drainage regional baseline investigations should be conducted in the general area of the site.

(2) It may be feasible to test local varieties of agricultural and natural vegetation in systematic plots to determine aerosol drift effects.

(3) An area of particular concern deals with lethal and sublethal stresses which may result from various effluent components.

Sublethal stresses can result in subtle changes in populations and communities as well as having effects on the individual organism. Synergistic effects within the effluent (this includes strange ionic imbalances) and in combination with environmental variables need to be investigated.

(4) The exact status of endangered species at the site should be determined. Such a study should include special requirements and mapping of habitats.

(5) All specimens of plants, animals, etc. collected during pre- and postoperational phases should be documented, stored and catalogued in museums, herbaria, etc. for future reference.

(6) A comprehensive aerial emission monitoring system should be established to determine the nature of cooling tower and generating system effluents and to improve the understanding of the microclimatological system of the site selected.

(7) The exact chemical and physical nature of the geothermal fluids must be determined, as well as the nature of any cooling system elements.

(8) Freshwater budgets must be determined for the site and conflicting demands assessed.

(9) Aquifers in the area of exploitation should be carefully monitored near the site and at a distance to detect any form of brine intrusion.

(10) Subsidence and seismic monitoring should be carried out on a continuing basis.

(11) A careful economic analysis comparing the relative value (including biological productivity) of the land as is, with potential benefits from geothermal energy production and a comparison with alternate production systems should be made.

(12) Baseline data should be acquired on effects of industry already sited on streams, rivers, bays or lagoons in the area and control data should be established from unaffected areas. The possibility of synergistic effects of these industrial wastes with geothermal wastes must not be overlooked.

(13) A comprehensive socio-economic investigation of the region should be conducted to determine the effects of development of the

energy resource and the effects on the area of shut down when the resource is exhausted.

(14) It should be determined if alternate methods of energy production will be able to supply the area after the geothermal resource is exhausted.

(15) The feasibility of a closed recirculating nonextractive system to utilize geopressured heat should be critically examined. Such a system would have many ecological advantages over an extractive system.

SUMMARY

Possible exploitation of geopressured-geothermal energy resources along the Gulf Coast of Texas and Louisiana has resulted in concern for potential environmental impacts. This report is a review of information on fish and wildlife resources of this region and a preliminary consideration of possible impacts of geothermal exploitation. Physical and biological environments of the area are summarized and special attention is given to ecological features that may influence or be affected by geopressured energy activities.

A number of potential impacts to fish and wildlife resources are recognized based on information on ecosystems of the region and the potential nature of commercial exploitation of geothermal resources. Such impacts are evaluated in relation to three possible location scenarios: (1) Production, generating, and disposal facilities on coastal land where access will be entirely by roads. (2) Production, generating and disposal facilities on low lying coastal marsh lands, primarily east of the Sabine River. (3) Production facilities offshore in estuaries, bayous, bays, lagoons, or the Gulf of Mexico; generating and disposal facilities on land. This assessment is based on technical information on the resource presented in Phase I of this project.

Processes and fluctuations among physical, chemical, and biological ecosystem components are emphasized to provide a baseline that will enable the identification of critical requirements for maintaining ecosystem productivity and integrity. Environmental effects of extractive exploitation of geopressured resources may be localized if spent geothermal fluids are disposed of by deep well injection and if only a few small power plants can be supported by the source. The latter may be a valid assumption if current predictions of the extent of the exploitable resource are accurate. Major constraints on such exploitation may be environmental impacts that could result from land subsidence and surface disposal of brines, if injection is not possible. Other major constraints may be the limited extent of geological

deposits suitable for exploitation and possible managerial problems. The constraints seem especially important when geopressured energy conversion systems are compared to solar, hydroelectric, cogeneration and tidal systems.

The exploitation of geopressured-geothermal resources will result in many of the problems associated with other types of geothermal deposits. These problems include industrial management for prevention of environmental damage, potential release of toxic substances from geothermal fluids (brine, ammonia, boron, and hydrogen sulfide), possible land subsidence, pipeline associated problems, electric power plant siting problems, transmission lines, solid wastes, organic pollutants, heat, and noise. Geopressured electrical generation activities may place demands on scarce water supplies.

An alternative method of exploiting geopressured heat resources --injection of clean surface water into a deep closed piping system and subsequent recovery of the heated water or steam--needs to be critically examined. Such a system would have many substantial ecological advantages over currently proposed extraction and disposal of geopressured fluids. But such a closed system also has disadvantages--particularly short-term economic ones.

An extensive, though not comprehensive review has been made of published and unpublished sources of information on fish and wildlife of the study area and on potential impacts resulting from exploitation of geopressured energy. The rationale for exploitation of geopressured resources has been reviewed in comparison with other potential energy conversion systems. The summary of ecological resources of the Gulf Coast includes human uses and natural ecological systems. The latter include marine, fresh water and terrestrial systems. These descriptions include both ecosystem process and biogeographical information. Considerable information is included on unique, rare or endangered species of the region. Included are lists of such plant and animal species and a bibliography on the ecology, distribution and behavior of vertebrate species of the area which are threatened with extinction.

Preliminary recommendations have been made with regard to siting of geopressured facilities. Areas that should be avoided include valuable fish and wildlife habitats. These include critical habitats for endangered species, as well as habitats essential to the life histories of species which are important economic resources of the area.

If technological problems could be solved, geopressured exploration in the open Gulf might be preferable to such activities in either terrestrial, fresh water or estuarine systems based on current knowledge. The latter systems appear to be much more sensitive to many of the types of stresses currently predicted for geopressured exploitation. Future knowledge of impacts which might result in the open Gulf may indicate that totally terrestrial siting may result in the most "controllable" system of the scenarios developed. Sites should be avoided which might result in damage to ground water supplies. Prairie sites should be preferred to forest or desert ones because restoration of vegetation of the latter sites by natural ecological succession requires a much longer time. Geothermal operations should be planned so that they do not interfere with essential behavior patterns of animals.

Of the proposed electrical conversion systems including flashed steam, binary cycle and total flow, the latter appears to be most ecologically desirable because it does not require an outside source of water for cooling. The binary system is preferable to the flashed steam method because much of the cooling can be accomplished, although not all of it in the climate of the coastal zone, by air cooling towers. In addition this system does not allow noncondensable gases to be passed to the atmosphere. Consideration should be given to cogeneration systems that utilize spent geothermal fluids (low grade heat) as an energy source.

Because of the great differences between composition of geothermal brines and that of sea water, and because of the presence of toxic substances originating in either geothermal reservoirs or in the technology of the geothermal conversion systems, geothermal fluids, particularly liquids, should not be released to terrestrial or aquatic environments. Deep well injection may prove to be a solution, however there may be unknown impacts resulting from such disposal methods. Because facilities utilizing geothermal heat must be located near the geothermal field, very careful planning should be implemented to determine if the field and any associated structures, including industries and urban developments, will be compatible with other uses of the site and its surroundings, such as for wildlife or agriculture.

A number of research needs related to the problems addressed in this report have been summarized. An extensive reference section has been compiled and includes an annotated bibliography indexed by subject matter. Lists of research scientists and/or institutions with expertise on the Texas-Louisiana coastal zone and/or geothermal energy are included.

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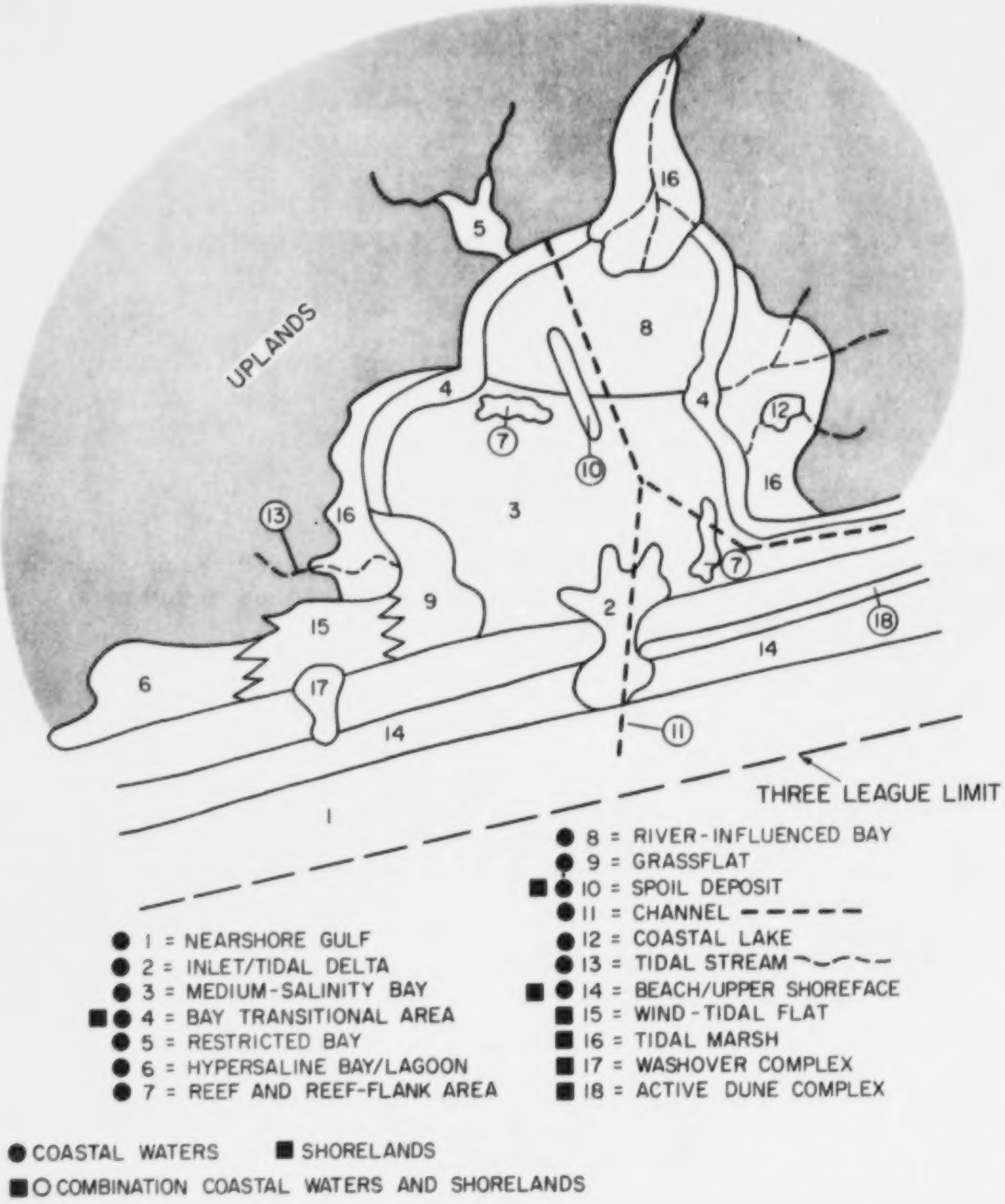
APPENDIX A

Examples of characteristic biota in each of the defined resource units for the Texas-Louisiana coastal waters and shorelines including a composite hypothetical bay system map.


UPLANDS
THREE LEAGUE LIMIT
1
2
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17
18
● 1 = NEARSHORE GULF
● 2 = INLET/TIDAL DELTA
● 3 = MEDIUM-SALINITY BAY
■● 4 = BAY TRANSITIONAL AREA
● 5 = RESTRICTED BAY
● 6 = HYPERSALINE BAY/LAGOON
● 7 = REEF AND REEF-FLANK AREA
● 8 = RIVER-INFLUENCED BAY
● 9 = GRASSFLAT
■● 10 = SPOIL DEPOSIT
● 11 = CHANNEL
● 12 = COASTAL LAKE
● 13 = TIDAL STREAM
■● 14 = BEACH/UPPER SHOREFACE
■ 15 = WIND-TIDAL FLAT
■ 16 = TIDAL MARSH
■ 17 = WASHOVER COMPLEX
■ 18 = ACTIVE DUNE COMPLEX
● COASTAL WATERS
■ SHORELANDS
■○ COMBINATION COASTAL WATERS AND SHORELANDS

Composite resource areas of Gulf Coastal waters and shorelands. From General Land Office of Texas (1976).

NEARSHORE GULF

Phytoplankton

Diatom	*Chaetoceros* spp.
Diatom	*Cyclotella* spp.
Diatom	*Nitzschia* spp.
Diatom	*Rhizosolenia* spp.
Diatom	*Skeletonema* spp.
Diatom	*Thalassionema* spp.
Diatom	*Thallasiothrix* spp.

Zooplankton

Copepod	*Acartia tonsa*
Copepod	*Paracalanus* spp.

Benthic Forms

Sea Pansy	*Renilla mulleri*
Starfish	*Astropecten antillensis*
Crab	*Calappa sulcata*
Eastern Murex	*Murex fulvescens*
Giant Cockle	*Dinocardium robustum*
Incongruous Ark	*Andana brasiliana*
Pen shell	*Atrina serrata*

Consumer Species

Menhaden	*Brevoortia patronus*
Blue Crab	*Callinectes sapidus*
Brown Shrimp	*Penaeus aztecus*
White Shrimp	*P. setiterus*
Mantis Shrimp	*Squilla empusa*
Croaker	*Micropogon undulatus*
Atlantic Threadfin	*Polydactylus octonemus*

Predator Species

Kingfish	*Scomberomorus cavalla*
Red Snapper	*Lutjanus compechanus*

INLET/TIDAL DELTA

Benthic Species

Mussel	*Modiolus demissus*
Oyster	*Crassostrea virginica*
Bryozoan	*Conopeum commensale*
Boring Sponge	*Cliona cleta*

Sessile Species, Especially on Jetties

Acorn Barnacle	*Chthamalus fragilis*
Zebra Perwinkle	*Littorina limeolata*
Oyster Drill	*Thais haemastoma*
Anemone	*Bunodosoma cavernata*
Stone Crab	*Menippe mercenaria*

Animals in Water Column

Bottlenose Dolphin	*Tursiops truncatus*
Cabbagehead Jellyfish	*Stomolophis meleagris*
Spot	*Leiostomus xanthurus*
Pinfish	*Lagodon rhomboides*
Blue Crab	*Callinectes sapidus*
Striped Mullet	*Mugil cephalus*
Southern Flounder	*Paralichthys lethostigma*
Shrimp	*Penaeus spp.*
Sheepshead	*Archosargus probatocephalus*

MEDIUM-SALINITY BAY

Producers

Diatom	*Thallasiothrix* spp.
Blue-green algae	*Anabaena* spp.
Blue-green algae	*Oscillatoria* spp.
Diatom	*Nitzschia* spp.
Diatom	*Navicula* spp.
Diatom	*Chaetoceros* spp.
Diatom	*Thalassionema* spp.

Benthic Species

Polychaete	*Mediomastus californiensis*
Polychaete	*Streblospio benedicti*
Nereid Worm	*Nereis succinea*
Dwarf Surf Clam	*Mulinia lateralis*
Common Mud Snail	*Nassarius vibex*
Constricted Macoma	*Macoma constricta*

Larger Consumers

Atlantic Croaker	*Micropogon undulatus*
Brown Shrimp	*Penaeus aztecus*
White Shrimp	*P. setiferus*
Menhaden	*Brevoortia patronus*
Anchovy	*Anchoa* spp.
Blue Crab	*Callinectes sapidus*

BAY TRANSITIONAL AREA

Producers

May have sparse stands of marsh plants or sea grass at the bay margin. Diatoms in sand if it is a mainland beach area.

Consumers

Contains seasonal concentrations of juvenile fish and crustaceans, with characteristic biota similar to that of the area/or areas adjacent to it.

RESTRICTED BAY

Producers

May contain scattered clumps of sea grass. Phytoplankton similar to those of medium-salinity bay.

Zooplankton

Similar to medium salinity bay.

Benthic Species

Deposit or filter feeders like those benthic species of medium salinity bays.

Larger Consumer Species

Similar to medium salinity bay species.

HYPERSALINE BAY/LAGOON

Producers

Seagrasses
Diatoms
Dinoflagellates
Blue-green algal mats

Primary Consumers

Copepod----------------------------------*Ascartia tonsa*
Amphipod --------------------------------*Gammarus macronatus*
Shrimp -- -------------------------------*Penaeus aztecus* (juveniles)
Blue Crab--------------------------------*Callinectes sapidus*
Sheepshead Minnow------------------------*Cyprinodon variegatus*
Pinfish --------------------------------- *Lagodon rhomboides*
Croaker . -------------------------------*Micropogon undulatus*

Higher Consumers

Spotted Sea Trout -------------------------*Cynoscion nebulosus*
Silverside---------------------------------*Menidia beryllina*
Redfish---------------------------------- *Sciaenops ocellatus*
Black Drum------------------------------- *Pogonias cromis*
Flounder --------------------------------*Paralichthys lethostigma*

REEF AND REEF-FLANK AREA

Producers

Phytoplankton (similar to Medium-Salinity, River-Influenced or Restricted Bays).

Filter Feeders

Eastern Oyster	Crassostrea virginica
Horse Oyster	Ostrea equestris
Atlantic Slipper	Crepidula fornicata
Hooked Muscle	Brachiodontes recurvus
Jingle Shell	Anomia simplex
Anemone	Aiptasiomorpha texaenis
Acorn Barnacle	Balanus eburneus
Serpulid Worm	Eupomatus dianthus
Sea Squirt	Molgula manhattensis

Predators and Parasites of Oysters

Boring Sponge	Cliona spp.
Blister Worm	Polydora websteri
Southern Lyster Drill	Thais haemostoma
Oyster "leeches	Stylochus spp.
Parasitic snail	Odostomia impressa
Blue Crab	Callinectes sapidus
Mud Crab	Panopeus herbsti
Stone Crab	Menippe mercenaria
Toadfish	Opsanus beta
Clingfish	Ctobiesox punctulatus

RIVER-INFLUENCED BAY

Producers

Diatom	Nitzschia spp.
Diatom	Skeletonema spp.
Diatom	Leptocylindricus spp.
Diatom	Thalassionema spp.
Diatom	Chaetoceros spp.
Blue-green algae	Nostoc spp.
Blue-green algae	Oscillatoria spp.
Widgeon Grass	Ruppia martima

Zooplankton

Cladoceran crustacean	Daphnia spp.
Copepod	Acartia tonsa
Copepod	Diaptomus spp.
Copepod	Bosmina spp.
Blue Crab zoea	Callinectes sapidus

Consumer Species

Common Rangia	*Rangia cuneata*
Amphipod	*Gammarus macronatus*
Grass Shrimp	*Palaemonetes* spp.
Striped Mullet	*Mugil cephalus*
Carolina Marsh Clam	*Polymesoda caroliniana*
Mitchell's Macoma	*Macoma mitchelli*
Brown Shrimp	*Penaeus aztecus*
White Shrimp	*P. setiferus*
Blue Crab	*Callinectes sapidus*
Menhaden	*Brevoortia patronus*
Spot	*Leiostomus xanthurus*
Croaker	*Micropogon undulatus*

GRASSFLATS-HYPERSALINE

Producers

Shoalgrass	*Diplanthera wrighti*
Widgeon Grass	*Ruppia maritima*
Gulf Halophila	*Halophila englemani*

Primary Consumers

Mud Crab	*Neopanope texana*
Amphipod	*Gammarus macronatus*
Brown Shrimp	*Penaeus aztecus (post-larvae)*
White Shrimp	*P. setiferus (post-larvae)*
Grass Shrimp	*Palaemonetes intermedius*
Blue Crab	*Callinectes sapidus*
Gulf Crab	*C. danae*
Polychaete worm	*Nereis pelagica*
Dwarf Surf Clam	*Mulinia lateralis*
Pointed Venus	*Anomalocardia cuneimeris*
Cross-barred Venus	*Chione cancellata*
Tellin-like Cumingia	*Cumingia tellinoides*
Scorched Mussel	*Brachiodontes exustus*
Pinfish	*Lagodon rhomboides*
Sheepshead	*Archosargus probatocephalus*

Secondary Consumers

Black Drum	*Pogonias cromis*
Longnose Killifish	*Fundulus similis*
Sheepshead Minnow	*Cyprinodon variegatus*

Spot	*Leiostomus xanthurus*
Redfish	*Sciaenops ocellata*
Pigfish	*Oathopristes chrysura*
Croaker	*Micropogon undulatus*

Predators

Spotted Sea Trout	*Cynoscion nebulosus*

GRASSFLATS-MODERATE SALINITY

Producers

Shoalgrass	*Diplanthera wrighti*
Widgeon Grass	*Ruppia maritima*
Turtle Grass	*Thalassia testudinum*
Manatee Grass	*Syringodium filiforme*
Gulf Halophila	*Halophila englemani*

Primary Consumers

Mud Crab	*Neopanope texana*
Amphipod	*Gammarus macronatus*
Brown Shrimp	*Penaeus aztecus*
White Shrimp	*P. setiferus*
Pink Shrimp	*P. duorarum*
Blue Crab	*Callinectes sapidus*
Gulf Crab	*C. danae*
Polychaete	*Nereis pelagica*
Dwarf Surf Clam	*Mulinia lateralis*
Scorched Mussel	*Brachiodontes exustus*
Half-folded Dove Snail	*Anachis avara*
Thick Tucine	*Phacoides pectinatus*
Cross-barred Venus	*Chione cancellata*
Bay Scallop	*Aequipecten amplicostatus*
Virgin Nerite	*Neritina virginea*
Southern Quahog	*Mercenaria campechiensis*
Jacknife	*Ensis minor*
Dwarf Arith	*Cerighium variabile*
Sea Cucumber	*Thyrone mexicana*
Caridean Shrimp	*Hippolyte* spp
Arrow Shrimp	*Tozeuma carolinensis*
Pinfish	*Lagodon rhomboides*
Sheepshead	*Archosargus probatocephalus*
Mullet	*Mugil cephalus*

Secondary Consumers

Black Drum--------------------------------*Pogonias cromis*
Longnose Killifish------------------------*Fundulus similis*
Sheepshead Minnow-----------------------*Cyprinodon variegatus*
Rainwater Killifish-----------------------*Luciana parva*
Spot -----------------------------------*Leiostomus xanthurus*
Redfish---------------------------------*Sciaenops ocellata*
Pigfish---------------------------------*Orthopristes chrysura*
Croaker--------------------------------*Micropogon undulatus*
Whelk ---------------------------------*Busycon contrarium*
Snapping Shrimp-------------------------*Alpheus heterochaelis*

Predators

Spotted Seatrout-------------------------*Cynoscion nebuosus*

SPOIL DEPOSITS

No characteristic biota. Extremely variable even after the area has stabilized.

CHANNELS

Producers

Phytoplankton characteristic of the bay and Gulf system are present. Various macroalgae using rocks or pilings for attachment are also present.

Benthic or attached species

Anemone--------------------------------*Bunodosoma cavernata*
Oyster----------------------------------*Crassostrea virginica*
Bryozoan ------------------------------*Conopeum commensale*
Mussel ---------------------------------*Chthamalus fragilis*
Stone Crab------------------------------*Menippe mercenaria*
Mud Crab-------------------------------*Panopeus herbstii*
Polychaete------------------------------*Laeonereis culveri*
False Limpet----------------------------*Siphonaria pectinata*

Weakly swimming species

Brown Shrimp----------------------------*Penaeus aztecus* (juveniles)
White Shrimp ---------------------------*P. setiferus* (juveniles)
Cabbagehead Jellyfish---------------------*Stomolophus meleagris*

Strong-swimming species

Bottlenose Dolphin-----------------------*Tursiops truncatus*
Spot-------------------------------------*Leiostomus xanthurus*
Flounder ---------------------------------*Paralichthys lethostigma*
Pinfish ----------------------------------*Lagodon rhomboides*
Striped Mullet----------------------------*Mugil cephalus*
Trout ------------------------------------*Cynoscion nebulosus*
Croaker ----------------------------------*Micropogon undulatus*
Redfish-----------------------------------*Sciaenops ocellata*

COASTAL LAKES

Consumers are similar to those in tidal marshes. The concentration of organisms may be lower. Marsh plants are present in sparse clumps, and the dominant producers are filamentous blue-green algae, often in mats. The algal mat has a very high primary productivity, and characteristic bacteria and microcrustaceans are associated with it.

TIDAL STREAM REACHES

Producers

Saltmeadow Cordgrass----------------------*Spartina patens*
Salt-marsh Bulrush------------------------*Scirpus maritimus*
Rush --------------------------------------*Juncus romerianus*
Green algae -------------------------------*Cladophora* spp.
Blue-green algae---------------------------*Phormidium* spp.

Benthic species

Common Rangia -----------------------------*Rangia cuneata*
Mitchell's Macoma -------------------------*Macoma mitchelli*
Dwarf Surf Clam----------------------------*Mulinia lateralis*
Carolina Marsh Clam -----------------------*Polymesoda caroliniana*
Nut Clam ----------------------------------*Nuculana* spp.
Virgin Nerite------------------------------*Neritina virginea*
Gastropod----------------------------------*Littoridina sphinctostoma*
Blue Crab----------------------------------*Callinectes sapidus*
Crayfish ----------------------------------*Cambarus diogenes*
River Shrimp-------------------------------*Macrobrachium ohione*

Fish

Bay Anchovy -------------------------------*Anchoa mitchelli*
Sheepshead Minnow -------------------------*Cyprinodon variegatus*
Gizzard Shad-------------------------------*Dorosoma cepedianum*
Alligator Gar -----------------------------*Lepisosteus spatula*

Rainwater Killifish------------------------*Luciana parva*
Silverside----------------------------------*Menidia beryllina*
Striped Mullet -----------------------------*Mugil cephalus*

BEACH/UPPER SHOREFACE

Producers

Blue-green algae
Diatoms
Phytoplankton

Interstitial Water Consumers

Microcrustaceans
Gastrotrichs
Ciliates
Tubellarians
Nematodes

Benthic Species

Mole Crab----------------------------------*Emertia portoricensis*
Ghost Crab --------------------------------*Ocypode quadrata*
Coquina-- - -------------------------------*Donax variabilis*
Moon Snail --------------------------------*Polinices duplicatus*
Lettered Olive ----------------------------*Olivia sayana*
Tube-building Work-------------------------*Diopatrea cupraea*
Sand Dollar--------------------------------*Melitta quinquesperforata*

Larger Nekton

Striped Mullet ----------------------------*Mugil cephalus*
Sea Catfish -------------------------------*Arius felis*
Atlantic Threadfin-------------------------*Polydactylus octonemus*
Tidewater Silverside ----------------------*Menidia beryllina*
Spotted Seatrout---------------------------*Cynoscion nebulosus*

WIND-TIDAL FLATS

Marsh plants
Blue-green algal mats
Diatom-------------------------------------*Nitzschia* spp.
Diatom-------------------------------------*Mastogloia* spp.
Diatom-------------------------------------*Navicula* spp.
Diatom-------------------------------------*Diplonesis* spp.

Primary Consumers and Deposit Feeders

Ciliates
Nematodes
Stout Razor--------------------------------*Tagelus plebius*
Jackknife Clam ---------------------------*Ensis minor*
Dwarf Surf Clam --------------------------*Mulinia lateralis*
Mud Shrimp -------------------------------*Callianassa jamaicense*
Ribbon Worm ------------------------------*Cerebratulus lacteus*
Parchment Worm ---------------------------*Chaetopterus variopedatus*
Lug Worm ---------------------------------*Arenicola cristata*
Polychaete -------------------------------*Neanthes succinea*

Higher Consumers, Scavengers, Omnivores

Mud Crab ----------------------------------*Rithopanopeus harrisi*
Common Mud Crab --------------------------*Panopeus herbsti*
Striped Hermit Crab ----------------------*Clibanarious vittatus*
Sheepshead Minnow ------------------------*Cyprinodon variegatus*
Redfish ----------------------------------*Sciaenops ocellatus*
Black Drum--------------------------------*Pogonias cromis*

TIDAL MARSHES

Producers

Benthic algal species
Smooth Cordgrass-------------------------*Spartina alterniflora*
Saltmeadow Cordgrass---------------------*Spartina patens*
Saltgrass---------------------------------*Distichlis spicata*
Glasswort --------------------------------*Salicornia bigelovi*
Rush--------------------------------------*Juncus romerianus*
Salt-marsh Bulrush -----------------------*Scirpus maritimus*

Primary Consumers

Amphipod ---------------------------------*Gammarus macronatus*
Grass Shrimp -----------------------------*Palaemonetes* spp.
Polychaete--------------------------------*Laeonereis culveri*
Marsh Periwinkle -------------------------*Littorina irrorata*
Ribbed Mussel-----------------------------*Modiolus demissus*
Sailfin Molly-----------------------------*Poecilia latipinna*
Striped Mullet----------------------------*Mugil cephalus*
Fiddler Crab------------------------------*Uca* spp.
Brown Shrimp------------------------------*Penaeus aztecus*
White Shrimp -----------------------------*P. setiferus*
Pinfish-----------------------------------*Lagodon rhomboides*

Secondary consumers

Blue Crab---------------------------------*Callinectes sapidus*
Spot--------------------------------------*Leiostomus xanthurus*
Anchovy ----------------------------------*Anchoa mitchelli*
Tidewater Silverside ---------------------*Menidia beryllina*
Catfish ----------------------------------*Arius felis*
Gulf Killifish ---------------------------*Fundulus grandis*

WASHOVER CHANNEL COMPLEX

Producers

Algal mats
Glassworts--------------------------------*Salicornia* spp.
Cordgrass --------------------------------*Spartina* spp.
Cattail-----------------------------------*Typha latitola*

Consumers

Fiddler Crab -----------------------------*Uca* Spp.
Ghost Crab--------------------------------*Ocypode quadrata*
Shore birds
Tidal marsh fauna

ACTIVE DUNE COMPLEX

Rooted plants

Seashore Dropseed-------------------------*Sporobolus virginicus*
Saltmeadow Cordgrass ---------------------*Spartina patens*
Railroad Vine ----------------------------*Ipomoea pescaprae*
Sea oats ---------------------------------*Uniola paniculata*

Other species, mostly transients

Tiger beetle------------------------------*Cincindela* spp.
Kangaroo rat -----------------------------*Dipodomis* spp.
Jackrabbit -------------------------------*Lepus californicus*
Rattlesnake ------------------------------*Crotalus adamanteus*
Coyote------------------------------------*Canis latrans*
Shorebirds

APPENDIX B

Plant species most directly threatened with extinction in at least the Texas coastal part of their geographic distribution. Yes and no statements concerning distributions within fairways indicate that the species has or has not been reported from the counties located in geothermal fairways. For each species the following information is given: botanical name, common name, and information on frequency and distribution. On a frequency scale of 1 to 7, ranging from abundance to extinction, only the highest numbers are included in this list:

"5" - scarce, endangered in Texas
"6" - very rare, acutely endangered in Texas.
"7" - presumed extinct, with no record since 1930 in Texas.

The extent of the known distribution is indicated by the following letter symbols:

"A" - distributed widely on the continent or in the world.
"B" - distributed broadly but regionally in North America and extending into Texas.
"C" - distributed widely in Texas.
"D" - distributed over several of the vegetational areas of Texas.
"E" - distributed in two of the vegetational areas in Texas.
"F" - distributed in one vegetational area of Texas.
"G" - distribution limited to 4 to 8 counties in one vegetational area.
"H" - distribution limited to 1 to 3 counties in one vegetational area.
"I" - known only from one or a few populations; explicit information occasionally provided.

See Figure 7 in text for map of Texas vegetation areas. If the letter "A" or "B" is not given in the symbolic notation, it is implied that the species is endemic to Texas (i. e., it occurs only in Texas). For example, the notation below Habenaria lacera, 5-I (B), means that the species is scarce and endangered in Texas, has a very local distribution in Texas, but is widely distributed over regions of North America. Good information on abundance in other areas is not available, therefore no implication as to an endangered status is made for these areas.

RARE AND ENDANGERED
PLANTS NATIVE TO TEXAS

RIO GRANDE PLAINS VEGETATIONAL AREA (TAMAULIPAN AND CHIHUAHUAN)

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Achyranthes aspera (Amaranth fam.)	Rough Chaff-flower	6-I(B)	Santa Ana Natl. Wildlife Refuge only, Hidalgo Co.	Yes
Ambrosia cheiranthifolia (Sunflower fam.)	Gray Ragweed	6-I(B)	San Patricio Co.	Yes
Amoreuxia wrightii (Cochlospermum fam.)	Yellowshow	6-H(B)		Yes
Amyris madrensis (Citrus fam.)	Mountain Torchwood	5-H(B)		Yes
Anthericum chandleri (Lily fam.)	Lila de los llanos	6-H(B)	Cameron Co.	Yes
Aristolochia marshii (Birthwort fam.)	Marsh Birthwort or Tacopate	6-I(B)	Santa Ana Natl. Wildlife Refuge, Hidalgo Co.	Yes
Asclepias prostrata (Milkweed fam.)	Creeping Milkweed	6-I(B)	near Roma, Starr Co.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Atriplex klebergorum (Goosefoot fam.)	Kleberg Saltbush	6-I	Kleberg & Webb cos.	No
Cardiospermum dissectum (Soapberry fam.)	Slashleaf Heartseed	6-I(B)	Starr Co.	No
Carlowrightia parviflora (Acanthus fam.)	Small Wrightwort	6-I(B)		No
Cephalanthus salicifolius (Madder fam.)	Mexican Buttonbush	7-I(B)	Hidalgo Co.	Yes
Chloris inflata (Grass fam.)	Puffy Fingergrass	6-I(B)	Cameron Co.	Yes
Chloris texensis (Grass fam.)	Texas Windmillgrass	6-E; info. needed	cf. Coastal Prairie	Yes
Cienfuegosia drummondii (Mallow fam.)	Yellow Fugosia	5-H(B)		No
Citharexylum berlandieri (Vervain fam.)	Orcajuela	5-H(B)	Cameron & Willacy cos.	Yes
Clappia suaedaefolia (Sunflower fam.)	Fleshy Clap Daisy	6-H(B)		No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Colubrina greggii var. *greggii* (Buckthorn fam.)	Sierra Snakewood	6-I(B)	palm groves, S. Cameron Co.	Yes
Coursetia axillaris (Legume fam.)	Baby-bonnets	5-F(B)	Hidalgo, Duval, Jim Hogg, San Patricio, Kleberg cos.	Yes
Croton soliman (Spurge fam.)	Soliman	6-I(B)	two plants in E. Cameron Co.	No
Dicliptera vahliana (Acanthus fam.)	Tropical Mudwort	6/7-I(B)	Santa Ana Natl. Wildlife Refuge, 1960 only; Hidalgo Co.	Yes
Dyschoriste crenulata (Acanthus fam.)	Wavy Dyschoriste	5-I(B)	Cameron, Hidalgo, Starr, Willacy cos.	Yes
Dyssodia tephroleuca (Sunflower fam.)	Ashy Dogweed	6-I	Starr & Zapata cos.	No
Echinocactus asterias (Cactus fam.)	Star Cactus	6-I(B)	Hidalgo & Starr cos.; info. needed.	Yes
Echinocereus melanocentrus (Cactus fam.)	Blackspot Hedgehog	6-I(B)	in heavy brush, Jim Wells & Kleberg cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Egletes viscosa (Sunflower fam.)	Tropicdaisy	6-I(B)	SW Cameron & Hidalgo cos.	Yes
Eragrostis palmeri (Grass fam.)	Rio Grande Lovegrass	6-I(B)	Harlingen, Cameron Co.	Yes
Eriogonum greggii (Knotweed fam.)	Gregg Wild-buckwheat	7-I(B)	Hidalgo Co.	Yes
Esenbeckia berlandieri (Citrus fam.)	Jopoy	7-I(B)	Cameron Co.	Yes
Frankenia johnstonii (Frankenia fam.)	Johnston Frankenia	6-I	Starr & Zapata cos.	No
Grindelia oolepis (Sunflower fam.)	Plains Gumweed	5-H		Yes
Helietta parvifolia (Citrus fam.)	Barreta	6-I(B)	Hidalgo & Starr cos.	Yes
Hoffmanseggia tenella (Legume fam.)	Slender Rushpea	6/7-I	Nueces & Kleberg cos.	Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Justicia runyonii (Acanthus fam.)	Runyon Justicia	6-I(B)	Cameron & Goliad cos.	Yes
Lophophora williamsii (Cactus fam.)	Peyote	5-D(B)	cf. Edwards Plateau & Trans-Pecos	Yes
Manihot walkerae (Spurge fam.)	Walker Manihot	7-I(B)	S. W. Hidalgo Co.	Yes
Marsilea mexicana (Pepperwort fam.)	Mexican Pepper-wort	6-I(B)	Aransas Co.	Yes
Matelea radiata (Milkweed fam.)	Falfurrias Milkvine	7-I	Brooks Co., 1909	No
Nephropetalum pringlei (Cacao fam.)	Pringle Kidneypetal	7-I	Hidalgo Co., 1888	Yes
Notholaena schaffneri (True Fern fam.)	Schaffner Cloakfern	5-D(B)	cf. Edwards Plateau & Trans-Pecos	Yes
Paronychia congesta (Pink fam.)	Bushy Whitlow-wort	6-I	Jim Hogg Co.	No
Polianthes runyonii (Amaryllis fam.)	Runyon Huaco	5/6-H(B)		Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Polygonum striatulum (Knotweed fam.)	Kleberg Knotweed	6-I	Brooks & Kleberg cos.	No
Prunus minutiflora (Rose fam.)	Texas Almond or Small-flower Peach-Brush	5-D	cf. Edwards Plateau & North-Central Texas	Yes
Sabal texana (Palm fam.)	Palma de Micharos	5-I(B)	S. Cameron Co.	Yes
Sedum texanum (Orpine fam.)	Texas Stonecrop	5-H? (B)	Coastal cos.	Yes
Serjania incisa (Soapberry fam.)	Slashleaf Serjania	6-I(B)	Kleberg Co.	No
Sida tragiaefolia (Mallow fam.)	Ear-leaf Sida	6-E(B)	cf. Trans-Pecos	Yes
Stenandrium fascicularis (Acanthus fam.)	Brush Stenandrium	6/7-I(B)	Calhoun, Nueces, Webb, Willacy cos.	Yes
Taxodium mucronatum (Taxodium fam.)	Montezuma Bald Cypress	6-I(B)	Cameron, Hidalgo	Yes
Tetramerium platystegium (Acanthus fam.)	Montell Fourwort	6-E	Kinney, Starr cos.; cf. Edwards Plateau	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Tournefortia volubilis (Borage fam.)	Tournefort Vine	6-I(B)	Cameron Co. only	Yes
Turnera diffusa (Turnera fam.)	Damiana	6-H(B)	Starr & Jim Hogg cos.	No
Urtica chamaedryoides var. runyonii (Nettle fam.)	Southmost Nettle	6-I	Cameron Co.	Yes
Willkommia texana (Grass fam.)	Willkommia	5/6-H	Coastal Bend cos.	Yes
Wissadula amplissima (Mallow fam.)	Big Yellow Wissadula	5-I(B)	Cameron & Kenedy cos.	Yes
Wissadula periplocifolia (Mallow fam.)	White Wissadula	6-I(B)	Cameron Co., perhaps Willacy Co.	Yes
Wolffiella lingulata (Duckweed fam.)	Tongue Bog-mat	6-I(B)	Hidalgo Co. only	Yes
Xylosma flexuosa (Flacourtia fam.)	Brush-holly or Coronilla	6/7-H(B)		Yes

COASTAL PRAIRIE VEGETATIONAL AREA (TEXAN AND AUSTRORIPARIAN)

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Bothriochloa exaristata (Grass fam.)	Awnless Bluestem	5-H(B)	info. needed	Yes
Carex gigantea (Sedge fam.)	Giant Sedge	6-E(B)	Harris Co.; cf. East Texas	Yes
Carex tribuloides (Sedge fam.)	Sand Sedge	6-E(B)	Jefferson & Montgomery cos.; cf. East Texas	No
Chloris texensis (Grass fam.)	Texas Windmill-grass	6-E	info. needed; cf. Rio Grande Plains	Yes
Hymenoxys texana (Sunflower fam.)	Texas Bitterweed	7-I	Houston area, not collected since 1900	Yes
Iva imbricata (Sunflower fam.)	Mustang Island Sumpweed	6-I(B)	Mustang Island, Nueces Co.	Yes
Machaeranthera aurea (Sunflower fam.)	Houston Machaeranthera	6/7-I	near Houston	Yes
Oenothera sessilis (Evening-primrose fam.)	Coastal Evening-primrose	7-I(B)	last collected ca. 1858	Yes
Ophioglossum vulgatum (Adder's-Tongue fam.)	Common Adder's-Tongue	5-E(A)	cf. East Texas	Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Sabal minor, trunked form (Palm fam.)	Louisiana Palm	5-E(B)	cf. East Texas	Yes
Scirpus cubensis (Sedge fam.)	Cuban Bulrush	6/7-I(B)	known only from Eagle Nest Lake, Brazoria Co. Collected once in 1958.	Yes
Scleria baldwinii (Sedge fam.)	Baldwin Stonerush	6/7-I(B)	Harris Co.	Yes
Scleria minor (Sedge fam.)	Minor Nutrush	6-E(B)	Matagorda Co.; cf. East Texas	Yes
Thelypteris palustris var. haleana (True Fern fam.)	Southern Marsh Fern	5-E(B)	Jefferson Co.; cf. East Texas	No
Wolffiella gladiata (Duckweed fam.)	Sword Bog-mat	6-I(B)	Brazoria National Wildlife Refuge only	Yes
EAST TEXAS VEGETATIONAL AREA (AUSTRORIPARIAN)				
Amelanchier arborea (Rose fam.)	Serviceberry	6-I(B)		No
Aristolochia serpentaria (Birthwort fam.)	Virginia Snakeroot	6-G(B)		No
Armoracia aquatica (Mustard fam.)	Lake Cress	6-I(B)	Town Bluff Lake, Tyler Co.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Aster scabricaulis (Sunflower fam.)	Rough Stem Aster	6-I	Tyler & Van Zandt cos.	No
Astragalus soxmaniorum (Legume fam.)	Soxman Milkvetch	5-G	Hardin, Anderson, Rusk, Leon, Houston, Freestone, Smith cos.	No
Aureolaria dispersa (Figwort fam.)	Beaumont Aureolaria	7-I(B)	Beaumont, Jefferson Co.	No
Bartonia texana (Gentian fam.)	Texas Bartonia	6-I(B)	pitcher plant bog, Tyler Co.	No
Bartonia verna (Gentian fam.)	Spring Bartonia	6-I(B)	Tyler Co.	No
Calopogon barbatus (Orchid fam.)	Bearded Grasspink	6-I(B)	bog in Henderson Co.; between Silsbee & Kountze, Hardin Co.	No
Carex albolutescens (Sedge fam.)	Yellow-white Sedge	6-I(B)	Polk & Jefferson cos.	No
Carex atlantica (Sedge fam.)	Atlantic Sedge	6-I(B)	Hardin, Newton, Nacogdoches, Tyler cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Carex digitalis (Sedge fam.)	Digital Sedge	6-H(B)	Newton & Polk cos.	No
Carex gigantea (Sedge fam.)	Giant Sedge	6-H-E(B)	Harris & Polk cos.; cf. Coastal Prairie	Yes
Carex gracilescens (Sedge fam.)	Slender Sedge	6/7-I(B)	Jefferson Co.	No
Carex nigromarginata (Sedge fam.)	Florida Sedge	6-I(B)	Nacogdoches & Newton cos.	No
Carex physorhyncha (Sedge fam.)	Hidalgo Sedge	5-I-E(B)	Smith, Walker, Jefferson cos.; cf. North-central Texas	No
Carex tenax (Sedge fam.)	Wire Sedge	6-I(B)	E. Hardin Co.	No
Carex tribuloides (Sedge fam.)	Bristle-bract Sedge	6-E(B)	cf. Coastal Prairie	No
Carya myristicaeformis (Walnut fam.)	Nutmeg Hickory	5-H(B)	San Augustine, Jefferson, San Jacinto cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Centaurium pulchellum (Gentian fam.)	Showy Centaury	6-I(B)	Hardin Co.	No
Conyza bonariensis (Sunflower fam.)	Buenos Aires Conyza	6-I(B)	Brazos & Orange cos.	No
Cuphea carthagensis (Loosestrife fam.)	Tropical Waxweed	6-I(B)	along Neches River near Evadale, Hardin Co.	No
Cuphea glutinosa (Loosestrife fam.)	Sticky Waxweed	6-I(A)	Tyler Co.	No
Cypripedium calceolus (Orchid fam.)	Yellow Ladies' Slipper	6-E(B)	Nacogdoches & Newton cos.; cf. Plains Country	No
Dioclea multiflora (Legume fam.)	Boykin Clusterpea	6-I(B)	Jasper & Tyler cos.	No
Dioscorea quaternata (Yam fam.)	Caddo Yam	6-I(B)	Harrison & Jasper cos.	No
Dryopteris ludoviciana (True Fern fam.)	Jack Gore Baygall	6-I(B)	Hardin Co.	No
Eleocharis elongata (Sedge fam.)	Slim Spike-sedge	6-I(B)	Hardin Co.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Erythronium rostratum (Lily fam.)	Yellow Dog's-tooth-Violet	6-I(B)	Hardin, Sabine, San Augustine cos.	No
Galactia erecta (Legume fam.)	Straight Milk-pea	6-I(B)	Polk & Tyler cos.	No
Galium hispidulum (Madder fam.)	Hairy Bedstraw	6-I(B)	Hardin Co.	No
Geum vernum (Rose fam.)	Spring or Heartleaf Avens	6-I(B)		No
Hedyotis purpurea (Madder fam.)	Purple Bluet	6-I(B)	Newton Co. only	No
Hibiscus aculeatus (Mallow fam.)	Sharp Rose-Mallow	6-I(B)	Hardin Co.	No
Hibiscus grandiflorus (Mallow fam.)	Bigflower Rose-Mallow	6-I(B)	Hardin Co.	No
Ilex ambigua (Holly fam.)	Carolina Holly	5-G(B)		No
Ilex cassine (Holly fam.)	Dahoon Holly	6-I(B)	Brazoria Co. only	Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Ilex montana (Holly fam.)	Mountain Winter-berry	6-H(B)	Hardin & Jasper cos.	No
Ilex myrtifolia (Holly fam.)	Myrtle Holly	7-I(B)	Brazoria Co.?; no precise info.	Yes
Ilex verticillata (Holly fam.)	Black-alder	6-I(B)	Sabine River, Orange Co.	No
Impatiens capensis (Touch-me-not-fam.)	Spotted Touch-me-not	5-H(B)	Cass & Hardin cos.	No
Isotria verticillata (Orchid fam.)	Whorled Pogonia	6-I(B)	Cass, Nacogdoches, Tyler cos.	No
Juncus debilis (Rush fam.)	Weak Rush	6-I(B)	Newton & Polk cos.	No
Lactuca graminifolia (Sunflower fam.)	Grass Lettuce	6-I-E(B)	cf. Trans-Pecos	No
Leavenworthia aurea (Mustard fam.)	Golden Yelloweye	6-G(B)		No
Leitneria floridana (Corkwood fam.)	Corkwood	5-I? (B)	near Angleton & Lake Jackson, Brazoria Co.	Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Lespedeza violacea (Legume fam.)	Prairie Clover	6-H(B)		No
Liatris cymosa (Sunflower fam.)	Branched Gayfeather	5-H	Brazos, Walker, Washington cos.	No
Liatris tenuis (Sunflower fam.)	Slender Gay-feather	5-G	Angelina, Jasper, Sabine, Tyler cos.	No
Lindera benzoin (Laurel fam.)	Spicebush	5-E(B)	cf. Edwards Plateau	No
Lithospermum tuberosum (Borage fam.)	Bulb Gromwell	7-I(B)	Brazoria Co., 1914; Polk Co., 1914	Yes
Lythrum salicaria (Loosestrife fam.)	Slenderspike Loosestrife	6-I	F.M. road to Sour Lake, Hardin Co.	No
Magnolia ashei (Magnolia fam.)	Ashe Magnolia	7-I(B)	info. needed	No
Magnolia fraseri (Magnolia fam.)	Mountain Magnolia	6-H(B)	Jasper Co.	No
Magnolia pyramidata (Magnolia fam.)	Pyramid Magnolia	6-I(B)	Jasper & Newton cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Monotropa uniflora (Heath fam.)	Indian Pipe	6-G(B)	Cass, Hardin, Newton, San Jacinto, Titus, Harrison cos.	No
Ophioglossum crotalophoroides (Adder's-Tongue fam.)	Bulbous Adder's-Tongue	6-E(B)	cf. Edwards Plateau	No
Ophioglossum nudicaule (Adder's-Tongue fam.)	Fragile Adder's-Tongue	6-I(B)	Hardin Co.	No
Ophioglossum vulgatum (Adder's-Tongue fam.)	Common Adder's-Tongue	5-E(A)	cf. Coastal Prairie	No
Panicum ensifolium (Grass fam.)	Sword-leaf Panic Grass	6-H(B)	Nacogdoches & Newton cos.	No
Parentucellia viscosa (Figwort fam.)	Sticky Parentucellia	6-G(B)	Cass, Jasper, Morris, Titus cos.	No
Phlox nivalis subsp. texensis (Phlox fam.)	Trailing Phlox	5-H		No
Physostegia micrantha (Mint fam.)	Hart Creek Dragonhead	6-I	S. E. of Mt. Pleasant, Titus Co.; Cass & Hardin cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Polygonatum biflorum (Lily fam.)	Great Solomon's Seal	6-H(B)	Sabine, Grayson, Cass cos.	No
Prenanthes altissima (Sunflower fam.)	Tall Rattlesnake Root	6-H(B)	Newton Co.	No
Prenanthes barbata (Sunflower fam.)	Barbed Rattlesnake Root	6-H(B)	Newton & Hardin cos.	No
Psilotum nudum (Clubmoss fam.)	Whiskfern	6-I(B)	one plant, Hardin Co.	No
Pyrus arbutifolia (Rose fam.)	Red Chokeberry	5-F(B)	Angelina, Bowie, Hardin, Jasper, Polk, Sabine, Tyler cos.	No
Rhexia alifanus (Melastoma fam.)	Rose Meadow-beauty or Deergrass	6-I(B)	Hardin Co.	No
Rhynchospora filifolia (Sedge fam.)	Bristleleaf Beakrush	6-H(B)	Hardin & Waller cos.	No
Rhynochospora grayi (Sedge fam.)	Gray Beakrush	6-H(B)	Jasper & Liberty cos.	No

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION COUNTIES	FAIRWAYS
Ruellia pinetarum (Acanthus fam.)	Pinebarren Ruellia	7-I(B)	Harris Co., 1872; Orange & Wood cos.	No
Sabal minor, trunked form (Palm fam.)	Louisiana Palm	5-E(B)	cf. Coastal Prairie	No
Sabatia brachiata (Gentian fam.)	Narrow-leaf Rose-gentian	6-I(B)	Hardin Co.	No
Sabatia campanulata (Gentian fam.)	Bell-flowered Rose-gentian	6-I(B)	Hardin Co.	No
Sanguinaria canadensis (Poppy fam.)	Bloodroot	6-I(B)	Little Cow Creek, Newton Co.; S. of Milam, Sabine Co.	No
Schoenolirion croceum (Lily fam.)	Yellow Sunnybell	6-I(B)	Tyler, Hardin, Jasper cos.	No
Scirpus etuberculatus (Sedge fam.)	Canby Bulrush	6-I(B)	Hardin Co.	No
Scleria minor (Sedge fam.)	Minor Nutrush	6-E(B)	Newton Co.; cf. Coastal Prairie	Yes

GENERA/SPECIES	COMMON NAME	RARENESS	DISTRIBUTION	
			COUNTIES	FAIRWAYS
Sebastiana fruticosa (Spurge fam.)	Sebastian Bush	5-F(B)		No
Solidago auriculata (Sunflower fam.)	Eared Goldenrod	5-I(B)	Harrison, Jasper, Newton cos.	No
Solidago caesia (Sunflower fam.)	Bluestem Goldenrod	5-I(B)		No
Stewartia malacodendron (Camellia fam.)	Silky Camellia	6-I(B)	near Burkeville, Newton Co.	No
Thelypteris palustris var. haleana (True Fern fam.)	Southern Marsh Fern	5-E(B)	Waller & Colorado cos.; cf. Coastal Prairie	No
Trillium texanum (Lily fam.)	Texas Trillium	6-G	Cass, Houston, Panola, Nacogdoches, Smith, Hardin cos.	No
Utricularia purpurea (Bladderwort fam.)	Purple Bladderwort	6-I(B)	Hardin Co.	No
Utricularia vulgaris (Bladderwort fam.)	Common Bladderwort	6-I(B)		No
Wahlenbergia marginata (Bluebell fam.)	Bellflower	6-I(B)	Hardin Co.	No

APPENDIX C

The status, distribution, and ecology of endangered vertebrates of coastal Texas and Louisiana (adapted from TOES, 1975). The status of taxa are defined as follows:

Endangered (E) - in danger of extinction in all or most of its geographic range in the United States, particularly in Texas.

Threatened (T) - depleated or impacted by man so as likely to become endangered in the near future.

Peripheral (P) - endangered or threatened in the United States, especially in Texas, although not in its range as a whole.

The present vertebrate list is cross-referenced with those of the Texas Parks and Wildlife Department (TPWD) and the U. S. Fish and Wildlife Service (F&WS). If not considered (NC) by these agencies, or the animal's status is undetermined by them (SU), these additional designations are given. If listed in the RED DATA BOOK of the International Union for the Conservation of Nature, an asterisk (*) is placed by the Texas Organization for Endangered Species (TOES, 1975) designation. Yes or no statements concerning fairways indicate the probability that the species occurs in these areas although it does not imply that it has been documented within the fairway. Brief statements of distribution and preferred habitat in Texas and reasons for the assigned status are also given.

Endangered Animal Species
MAMMALS

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Little Brown Bat (Myotis lucifugus)	P	NC	NC	Hudspeth and Newton counties	No	Roost in caves, mines, buildings, or rock crevices	Small population size
Southern Myotis (Myotis austroriparius)	P	NC	NC	Panola, Bowie, and Newton counties	No	Roost in caves and buildings	Small population size
Southern Yellow Bat (Lasiurus ega)	P	NC	NC	Lower Rio Grande Valley	Yes	Roost in palm grove near Brownsville	Habitat destruction
Prairie Vole (Microtus ochrogaster ludovicianus)	P	NC	SU	Collected once in 1905 at Sour Lake, Hardin Co.	No	Meadows in piney woods	Unknown; small population size?
Gulf Stream Beaked Whale[2] (Mesoplodon europaeus)	T	NC	NC	Gulf Coast	Yes	Offshore waters	Small population size
Goose-beaked Whale (Ziphius cavirostris)	T	NC	NC	Gulf Coast	Yes	Offshore waters	Unknown
Sperm Whale (Physeter catodon)	T	E	T	Gulf Coast	Yes	Offshore waters	Whaling
Pygmy Sperm Whale[2] (Kogia breviceps)	T	E	NC	Gulf Coast	Yes	Offshore waters	Whaling
Dwarf Sperm Whale[2] (Kogia simus)	T	E	NC	Gulf Coast	Yes	Offshore waters	Whaling
Pygmy Killer Whale[2] (Feresa attenuata)	T	NC	NC	Gulf Coast	Yes	Offshore waters	Whaling

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Finback Whale (Balaenoptera physalus)	E*	E	T	Gulf Coast	Yes	Offshore waters	Whaling
Blue Whale (Balaenoptera musculus)	E*	E	T	Gulf Coast	Yes	Offshore waters	Whaling
Black Right Whale (Balaena glacialis)	E*	E	T	Gulf Coast	Yes	Offshore waters	Whaling
Red Wolf (Canis rufus)	E	E	E	Galveston-Chambers-Brazoria Co. area	Yes	Coastal & prairie marshes	Habitat destruction; predator control; disease
Black Bear (Ursus americanus)	E	NC	NC	Statewide; chiefly S. E. & Trans-Pecos	No	Forested habitats with low human population density.	Deforestation; Predator-control; hunting
River Otter (Lutra canadensis)	T	NC	NC	Trinity River & eastward	No	Marshes, river or stream habitat	Trapping pressure
Mountain Lion (Felis concolor)	E	NC	NC	Statewide but scattered.	Yes	Areas of low human population density	Hunting; predator control practices.
Ocelot (Felis pardalis)	P*	E	P	Lower Rio Grande valley & lower coast	Yes	Subtropical woodland	Predator control; habitat destruction.
Jaguarundi (Felis yagouaroundi)	P	NC	P	Lower Rio Grande valley & lower coast	Yes	Subtropical woodland	Predator control; Hunting; habitat destruction.
West Indian Seal (Monachus tropicalis)	E*	NC	T	Gulf Coast	Yes	Sandy beaches	Hunted commercially.
Manatee (Trichechus manatus)	E*	E	E	Gulf Coast	Yes	Warm, vegetated water	Inadvertently killed by motor boat propellers. Hunted commercially.

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Felis onca	?	E	?	Lower Rio Grande Valley	Yes	Chaparral, open forests	Small population hunting
[2] Status uncertain due to incomplete information.							
BIRDS							
Brown Pelican (Pelecanus occidentalis)	E*	E	E	Lower & Central coastal areas	Yes	Coastal islands & bays	Pesticides human disturbance.
Olivaceous Cormorant (Phalacrocorax olivaceus)	P	NC	NC	Coastal zone; less frequently inland	Yes	Coastal islands, bays marshes	Pollution; marsh drainage
Reddish Egret (Dichromanassa rufescens)	E	NC	P	Coastal zone	Yes	Coastal islands & brackish marshes	Restricted distribution; pollution, pesticides.
White-faced Ibis (Plegadis chihi)	T	NC	SU	Coastal zone; less frequently inland	Yes	Coastal islands & marshes	Cultivation of habitat
Roseate Spoonbill (Ajaia ajaja)	P	NC	P	Coastal zone; less frequently inland	Yes	Coastal islands and marshes	Human disturbance (recovering)
Ross' Goose (Chen rossii)	T	NC	NC	Coastal zone; less frequently inland	Yes	Coastal prairies	Small population
Fulvous Tree Duck (Dendrocygna bicolor)	E	NC	NC	Coastal zone; less frequently inland	Yes	Freshwater marshes and prairies	Pesticides; Cultivation of habitat
Masked Duck (Oxyura dominica)	P	NC	P	Coastal zone	Yes	Coastal marshes & resacas	Small population marsh drainage
White-tailed Kite (Elanus leucurus)	P	NC	P	Lower Rio Grande valley; coast & east-central area	Yes	Prairies & farm country with clumps of trees	Indiscriminate shooting

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Swallow-tailed Kite (Elanoides forficatus)	T	NC	NC	Eastern half of state	Yes	Open Woodlands	Indiscriminate shooting; lumbering
Zone-tailed Hawk (Buteo albonotatus)	P	NC	P	Mexican Border region	Yes?	Steep canyons & river woodlands	Indiscriminate shooting
Gray Hawk (Buteo nitidus)	P	NC	P	Lower Rio Grande valley; less often coast & Trans-Pecos	Yes	Subtropical woodlands	Clearing of woodlands
White-tailed Hawk (Buteo albicaudatus)	P	NC	P	Coastal zone; less frequently inland	Yes	Coastal prairies and marshes	Indiscriminate shooting
Black Hawk (Buteogallus anthracinus)	P	NC	P	Along Rio Grande & in Davis Mts.	Yes?	River Woodlands	Clearing of woods; Indiscriminate shooting
Bald Eagle (Haliaeetus leucocephalus)	E*	E	E	Statewide	Yes	Lakes, reservoirs & large rivers	Pesticides; indiscriminate shooting
Golden Eagle (Aquila chrysaetos)	T	NC	NC	Statewide	Yes?	Mountains, hilly country	Indiscriminate shooting
Osprey (Pandion haliaetus)	E*	NC	SU	Statewide	Yes	Coastal zone; lakes & reservoirs	Pesticides; indiscriminate shooting
Peregrine (Falco peregrinus)	E*	E	E	Statewide	Yes	Coastal zone; lakes & mountains	Pesticides; nest robbing by falconers
Prairie Falcon (Falco mexicanus)	T	NC	T	Statewide, except extreme east	Yes	Open country of arid areas	Pesticides; nest robbing by falconers
Merlin (Falco columbarius)	T	NC	SU	Statewide	Yes	Open country	Pesticides

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Attwater's Prairie Chicken (*Tympanuchus cupido*)	E*	E	E	Coastal zone	Yes	Coastal prairies	Overgrazing; agriculture
Whooping Crane (*Grus americana*)	E*	E	E	Coastal zone	Yes	Coastal marshes & bays	Small population size; restricted winter range.
Jacana (*Jacana spinosa*)	P	NC	P	Lower & Middle coasts	Yes	Coastal marshes	Small population; drainage
American Oystercatcher (*Haematopus palliatus*)	P	NC	NC	Coasts	Yes	Coastal islands, beaches & mudflats	Small population?
Eskimo Curlew (*Numenius borealis*)	E*	E	E	Coastal zone	Yes	Coastal prairies	Small population
Sooty Tern (*Sterna fuscata*)	P	NC	NC	Coastal zone	Yes	Coastal islands	Disturbance during nesting
Ferruginous Owl (*Glaucidium brasilianum*)	P	NC	P	Lower Rio Grande Valley	Yes	Subtropical woodland	Clearing of woodland
Ringed Kingfisher (*Megaceryle torquata*)	P	NC	NC	Lower Rio Grande Valley	Yes	Rio Grande	Small population
Red-cockaded woodpecker (*Dendrocopus borealis*)	E*	E	E	East of Trinity River	No	Mature open pine forest	Lumbering
Ivory-billed woodpecker (*Campephilus principalis*)	E*	E	E	Big Thicket region	No	Mature hardwood riverbottom forests	Lumbering
Beardless flycatcher (*Camptostoma imberbe*)	P	NC	P	Lower Rio Grande Valley	Yes	Subtropical woodland	Clearing of woodlands
Rose-throated Becard (*Platypsaris aglaiae*)	P	NC	P	Lower Rio Grande Valley	Yes	Subtropical woodland	Clearing of woodlands

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Yellow-green Vireo (*Vireo flavoviridis*)	P	NC	NC	Lower Rio Grande valley & coast	Yes	Subtropical woodland	Clearing of woodlands
Tropical Parula (*Parula pitiayumi*)	P	NC	P	Lower Rio Grande valley	Yes	Subtropical woodland	Clearing of woodlands
White-collared Seedeater (*Sporophila torqueola*)	P	NC	P	Lower Rio Grande valley	Yes	Pastures & weedy fields	Restricted distribution; small population size.
Botteri's Sparrow (*Aimophila botterii*)	P	NC	P	Lower Gulf Coast	Yes	Coastal prairie	Restricted distribution; small population size.
REPTILES							
American Alligator (*Alligator mississipiensis*)	E*	E	E	E. and coastal areas	Yes	Marshes, rivers, canals, ponds, & lakes	Indiscriminate killing; commercial hunting
Loggerhead Turtle (*Caretta caretta*)	E*	NC	E	Coastal zone	Yes	Gulf; shore to nest	Over-hunting & beach development
Green Turtle (*Chelonia mydas*)	E*	NC	E	Coastal zone	Yes	Gulf; shore to nest	Over-hunting & beach development
Leatherback Turtle (*Dermochelys coriacea*)	E*	E	E	Coastal zone	Yes	Gulf; shore to nest	Over-hunting & beach development
Hawksbill Turtle (*Eretmochelys imbricata*)	E*	E	E	Coastal zone	Yes	Gulf; shore to nest	Over-hunting & beach development
Ridley Turtle (*Lepidochelys kempi*)	E*	E	E	Coastal zone	Yes	Gulf; shore to nest	Over-hunting & beach development
Diamond-backed Terrapin (*Malachemys terrapin*)	T	NC	NC	Coastal zones	Yes	Salt marsh	Destruction of habitat & over-hunting for food.
Black-striped Snake (*Coniophanes imperialis*)	P	NC	NC	Cameron & Hidalgo Co.	Yes	Subtropical woodland	Woodland clearing

NAME	TOES	TPWD	F&WS	RANGE IN TEXAS	FAIRWAYS	PREFERRED HABITAT	REASON FOR STATUS
Speckled Racer (Drymobius margaritiferus)	P	NC	NC	Cameron County	Yes	Subtropical woodland; riparian areas	Woodland clearing; marsh drainage
Texas Cat-eyed Snake (Leptodeira septentrionalis)	P	NC	NC	Cameron, Hidalgo, Kennedy & Willacy Counties.	Yes	Subtropical woodlands; riparian areas	Woodland clearing; drainage
Louisiana Pine Snake (Pituophis melanoleucus ruthveni)	T	NC	NC	Big Thicket area; & Wood Co.	No	Longleaf pine woodland; sandy soil	Lumbering
Smooth Green Snake (Opheodrys vernalis)	T	NC	NC	N. Cent. Coastal zone	Yes	Coastal prairie	Cultivation; edification
AMPHIBIANS							
Houston Toad (Bufo houstonensis)	E*	E	E	SE Texas (endemic)	No	Loblolly pine forest; sandy soil	Lumbering; hybridization
Giant Toad (Bufo marinus)	P	NC	NC	Hidalgo, Starr & Zapata counties	Yes	Riparian areas; resacas	Drainage; clearing
Mexican White-lipped Frog (Leptodactylus labialis)	P	NC	NC	Cameron, Starr & Hidalgo Counties	Yes	Subtropical woodlands; riparian areas	Clearing; drainage
Mexican Tree Frog (Smilisca baudini)	P	NC	NC	Cameron & Hidalgo Counties	Yes	Subtropical woodland; resacas.	Clearing of woodlands

APPENDIX D

Some recent publications on the ecology, distribution and behavior of species of vertebrates of the coastal zone of Louisiana and Texas listed as endangered, threatened or rare by the Texas Organization for Endangered Species (1975). Several older or more general references are included. The "BA" number is the abstract number in Biological Abstracts.

Species included are:

AMPHIBIA

Bufo houstonensis - Houston Toad
Bufo marinus - Giant Toad
Leptodactylus labialis - Mexican White-lipped Frog
Smilisca baudini - Mexican Tree Frog

REPTILIA

Alligator mississipiensis - American Alligator
Caretta caretta - Loggerhead Turtle
Chelonia mydas - Green Turtle
Coniophanes imperialis - Black-striped Snake
Dermochelys coriacea - Leatherback Turtle
Drymobius margaritiferus - Speckled Racer
Eretmochelys imbricata - Hawksbill Turtle
Lepidochelys kempi - Ridley Turtle
Leptodeira septentrionalis - Texas Cat-eyed Snake
Malaclemys terrapin - Diamond-backed Terrapin
Opheodrys vernalis - Smooth Green Snake
Pituophis melanoleucus ruthveni - Louisiana Pine Snake

AVES

Aimophila botteri - Botteri's Sparrow
Ajaia ajaja - Roseate Spoonbill
Aquila chrysaetos - Golden Eagle
Buteo albicaudatus - White-tailed Hawk
Buteo albonotatus - Zone-tailed Hawk
Buteo nitidus - Gray Hawk
Buteogallus anthracinus - Black Hawk
Campephilus principalis - Ivory-Gilled Woodpecker
Camptostoma imberbe - Beardless Flycatcher
Chen rossi - Ross' Goose
Dendrocopus borealis - Red-cockaded Woodpecker

Dendrocygna bicolor - Fulvous Tree Duck
Dichromanassa rufescens - Reddish Egret
Elanoides forficatus - Swallow-tailed Kite
Elanus leucurus - White-tailed Kite
Falco columbarius - Merlin
Falco mexicanus - Prairie Falcon
Falco peregrinus - Peregrine Falcon
Glaucidium brasilianum - Ferruginous owl
Grus americana - Whooping Crane
Haematopus palliatus - American Oystercatcher
Haliaeetus leucocephalus - Bald Eagle
Jacana spinosa - Jacana
Megaceryle torquata - Ringed Kingfisher
Numenius borealis - Eskimo Curlew
Oxyura (Erismatur) dominica - Masked Duck
Pandion haliaetus - Osprey
Parula pitiayumi - Tropical Parula
Pelecanus occidentalis - Brown Pelecan
Phalacrocorax olivaceus - Olivaceous Cormorant
Platypsaris aglaiae - Rose-throated Becard
Plegadis chihi - White-faced Ibis
Sporophila torqueola - White-collared Seedeater
Sterna fuscata - Sooty Tern
Tympanuchus cupido attwateri - Attwater's Prairie Chicken
Vireo flavoviridis - Yellow-green Vireo

MAMMALIA

Balaenoptera musculus - Blue Whale
Balaenoptera physalus - Finback Whale
Eubalaena (Balaena) glacialis - Black Right Whale
Canis rufus - Red Wolf
Felis concolor - Puma or Mountain Lion
Felis pardalis - Ocelot
Felis yagouaroundi - Jaguarundi
Feresa attenuata - Pigmy Killer Whale
Kogia breviceps - Pygmy Sperm Whale
Kogia simus - Dwarf Sperm Whale
Lasiurus ega - Southern Yellow Bat
Lutra canadensis - River Otter
Mesoplodon europaeus - Gulf Stream Beaked Whale
Microtus ludovicianus - Prairie Vole
Monachus tropicalis - West Indian Seal
Myotis austroriparius - Southern Myotis
Myotis lucifugus - Little Brown Bat
Panthera onca - Jaguar

Physeter catodon - Sperm Whale
Trichechus manatus - Manatee
Ursus americanus - Black Bear
Ziphius cavirostris - Goose-beaked Whale

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Appendix E. Listing of pollution incidents at the Geysers geothermal field, California. Source: California Department of Fish and Game (personal communication).

Date	Pollution incident
11/3/75	Discharge of power generation wastewater into Big Sulphur Creek.
11/28/67	Siltation into Big Sulphur Creek from road building activities.
1/4/68	Unusual milky/soapy substance causing turbidity in Big Sulphur Creek from confluence with Squaw Creek to within 1/4 mile of Russian River.
1/5-6/68	Drilling muds from Geothermal Resources Rorabaugh #2 found spilling into Big Sulphur Creek. Samples of "Magcogel" and "Magcobar Foam #44" obtained. Bioassays indicated Magcobar 44 toxic to trout at concentration of 10 ppm.
1/11/68	Sumps for GRI wells Rorabaugh #2 and #3 filled, earthen dams soft. Investigators felt they presented a threat to Big Sulphur if rains continued.
10/2/68	Reduction of fish food organisms and spawning gravels in area of Union Oil road construction (PG&E Units 3 &4) (possible violation of Fish and Game Code Section 5650).
10/31/68	Silt and rock introduced to Big Sulphur as a result of road building.
11/13/68	Steelhead Trout population downstream from Union Oil Company road reduced to 1/4 that of July 16, 1968 levels.
9/10/71	20,000 gallons of cooling tower wastewater and debris discharged to Big Sulphur Creek after pipeline failure in Union Oil wastewater disposal system. Low-flow condition present in Big Sulphur Creek.
7/6/72	Drilling muds and waste materials discharged to Big Sulphur Creek when an earthen sump at a Union Oil drill site (Hoover Rig E2) broke. Test conducted with drilling mud samples (bentonite clay, tannithin and lignite) indicated these materials can be toxic to fishlife.

4/19/73	Drilling muds and waste materials discharged to Squaw Creek as a result of a leaking sump at Union Oil drill site (Ottoboni #10). Seeps of drilling waste materials continued until 23 of April.
7/17/73	Discharge of cooling tower condensate reported and verified by DFG wildlife protection personnel.
10/73	RWQCB cleanup on Abatement Order No. 73-101 for Geothermal Kinetics, Inc. Rorabaugh #1 Well. Discharge of sump wastes in tributary to Big Sulphur Creek.
10/73	RWQCB and Abatement Order No. 73-102 for Pacific Energy Corp. Well No. 47. Discharge of drilling wastes to surface of dirt roads will probably result in discharge to Big Sulphur Creek.
12/11/73	Letter from RWQCB informing PG&E power plant supervisor of (1) sand-blasting materials being discharged at power plants #1 and #2. These materials could pass into the waters of Big Sulphur Creek. (2) Trash and garbage dump located at power plants 9 and 10 which had not been approved by the RWQCB. (ref: 12,11,1973 letter to W. Pearce, PG&E plant superintendent from D. Snetsinger RWQCB. RWQCB files).
12/21/73	Recommendations from State WRCB regarding soil erosion and waste disposal at the Geysers state that: "The commonly expedient methods used in pit or sump construction disallows for proper design consideration against potential slope failure and/or the prevention of fluid infiltartion into subsurface materials. Percolation of fluids through bedrock fractures could affect the quality of local waters and promote instability of natural or man-made slopes." (ref: 12,21, 1973 Memorandum to Bob Tancreto, California Regional WQCB, Santa Rosa from State WRCB Geologist Gil Torres. RWQCB files).
2/5/74	Division of Oil and Gas notice of violation regarding unstable and overflowing sump for Union Oil Co. Well No. GDC 20-29.
2/5/74	Division of Wil and Gas notice of violation regarding unstable, washed out and eroded sump, natural springs draining at base for Union Oil Co. Well No. LF State 4597.

5/74 Approximately 2,000 gallons of water from the cooling tower basin and 50,000 to 70,000 gallons from the sediment basin emergency overflow drainage system of power plant Unit 5 & 6 discharged to the ground. Inspection of the plants also found oily discharges from stand pipes as a result of numerous spills from a waste oil and oil storage area. (ref: memorandum 5/28/74 to Tancreto, PG&E from D. Salisbury; 6/3/74 letter to Benkor CRWQCB, Santa Rosa from W. Pearce, PG&E. RWQCB files).

5/15/74 Condensate line from Unit 7 & 8 pond to Unit 11 broke at the drill rig water tie-in point. The tie-in weld broke, releasing condensate at the rate of 465 gpm. The total discharge was estimated at 28,000 gallons. There was a noticeable increase in turbidity in Squaw Creek noted. Parametrix personnel reported electroshocking data show fish to be healthy and active (?) (ref: Union 76 letter 5/22/74 to CRWQCB, Santa Rosa, attn: John Hannum).

6/3/74 50,000 to 75,000 gallons of steam condensate spilled from a ruptured pipe at PG&E plant #7. Water from this spill reached Squaw Creek. The spill was reported approximately two months after it happened. (ref: Letter 6/3/74 to CRWQCB from W. Pearce. CRWQCB files).

7/8/74 Spill of detergents into Squaw Creek from Union Oil Co. drilling rig wash water. Tests indicated that the material was toxic to fish.

8/20/74 A discharge of condensate water occurred at cooling tower #2. The water contained approximately 14 mg/l of iron in addition to the normal constituents found in the condensate. The high iron concentration was the result of an experiment by PG&E. The discharge reached Big Sulphur Creek and resulted in a red discoloration that persisted for approximately one hour (~10 ppm). (ref: memo (interoffice) to Bob Tancreto and Ben Kor from D. Snetsinger 8/21/74. CRWQCB files).

9/9/74 Mechanical failure of the fiberglass disposal line from Unit 5 & 6 settling pond discharged 4,500 gallons of condensate into Big Sulphur Creek. A fish kill and excessive siltation was noted. (ref: Union 76 letter 9/19/74 to CRWQCB. CRWQCB files).

9/16/74 A unit 5 & 6 settling pond overflow on 9/15/74 discharged ~ 45,000 gallons of condensate to Big Sulphur Creek. Improper procedures in water transfer blamed. No fish kill noted, however, Parametrix noted a higher than average ammonia and sulfate level present in Big Sulphur Creek. (ref: same as above).

1/6/75 Approximately 50 gallons of No. 2 diesel oil was spilled during routine fueling operations at the Ottoboni state well no. 20. The diesel was contained within a berm built for that purpose. Heavy rains overflowed the berm and released the diesel to Squaw Creek. (ref: Union 76 letter explaining the delay in reporting the spill to CRWQCB 1/15/75. CRWQCB files).

2/25/75 A water spill @Horner state well #1 in Lake Co. released approximately 8,000 gallons condensed steam which had been used for drilling water was pumped onto the ground by accident. The water percolated into the ground and there was no visable signs of contamination noted immediately after the accident. Mr. Pardini noted suds in High Valley Creek. (ref: Union 76 letter 3/17/75 to CRWQCB, attn: J. Robertson, RWQCB files).

3/31/75 Blow-out of Union Oil Co. Well No. GDC 65-28. Hillsides near well covered with greenish dust which washed into stream tributary to Big Sulphur Creek.

4/9/75 Construction efforts to control blow-out of Union Oil Co. Well No. GDC 65-28 result in high turbidity and sedimentation of Big Sulphur Creek and tributary (reportedly a continuing problem).

5/9/75 Discharge of cooling tower water from PG&E Unit #11 into Squaw Creek.

6/4/75 A flange broke at Unit 11 spilling an estimated 20,000 gallons of condensate to the ground. Of the amount spilled, most was contained in a basin but 10% was reported to have reached Squaw Creek. The flange is of the same type as installed at other units. (ref: PG&E letter 6/4/75 to CRWQCB, attn: Mr. Snetsinger; Interoffice memo 6/5/75 to B. Tancreto, B. Kor, & D Snetsinger from D. Salisbury. CRWQCB files).

6/6/75 A spill of ~10,000 gallons from Unit 3 consisted of steam condensate and water from a tributary of Big Sulphur Creek. A vitrified clay pipe broke, and drained the water 1/2 mile down the hill carrying mud into the creek. Duration of the spill

	was approximately 4 hours. The clay pipe is being replaced with glass lined carbon steel pipe. (ref: PG&E letter 6/10/75 to CRWQCB, attn: Mr. Snetsinger. CRWQCB files).
9/5/75	Water was discharged from a Unit 10 cooling tower header pipe flange to the ground. The flange broke during a Unit 10 shutdown releasing ~148,500 gallons of steam condensate in 4 minutes. The spill ran down 1/4 mile of hillside to Cobb Creek and eventually to Big Sulphur Creek. There was no visible damage to fish life or excess siltation in Big Sulphur Creek noted. (ref. PG&E letter 9/10/75 to CRWQCB, attn. Mr. Snetsinger. CRWQCB files).
8/6/75	Discharge of material from Shell Oil Company Well U.S. Geothermal One-1 on Federal lease, Lake County, Sec. 1 T10N, R8W, MDB&M. Grey material discharged from well covered approximately 3-4 acres coating ground surface, shrubs, and trees. Portion entered intermittent tributary to Dry Creek. Bioassays indicated leachate was toxic to fish life.
12/75	Spill of drilling mud from PEC well near Eagle Rock Mine. Mud return line broke and discharged to tributary to Big Sulphur Creek.
3/16/76	Condensate pipeline failure at Unit 2 power plant, resulting in discharge of 4,260 gallons. The pipeline was of rebar reinforced concrete and had been badly corroded by the condensate. No extensive fish kill was observed in the stream below the discharge site.
5/26/76	Spill of 4,000 gallons of steam condensate at Unit 11, with discharge to Squaw Creek. Spill caused by failure of a check valve in the condensate return line to an injection well. A total of 54 dead Steelhead Trout were found in a stream section of 200 yards below the discharge.
3/28/77	Single vehicle accident involving Shell Oil Company truck delivering fuel oil to McCulloch Oil Company Geothermal rig near Glenbrook, Lake County. About 2,000 gallons of fuel oil was discharged with approximately 50 gallons entering Alder Creek. Four dead fish observed in lower Alder Creek.
4/6/77	Spill of 2,500 gallons of steam condensate at PG&E Geysers Unit 8. Excessive pumping of sediment pond caused low water levels, activating automatic valve which prevented usual discharge. The high water level alarm of the cooling tower

basin was inoperative, which resulted in an overflow of the basin of about 250 gal/min for 10 minutes. The condensate discharged into Upper Geyser Canyon Creek but apparently did not reach Big Sulphur Creek. The condensate soaked into ground which was dry as a result of drought conditions.

4/18/77	Failure of cut slope during Union Oil Co. road construction resulted in slide of soil, rocks, and debris entering Big Sulphur Creek above Unit 1 & 2. Road was being improved for access to Unit 14. Substantial pool area was filled, and siltation of stream. Stream was highly turbid when inspected on May 2, due to runoff from recent storm.

APPENDIX F

The following annotated bibliography is a compilation of available information pertinent to all facets related to the exploitation of geopressure-geothermal energy described in the preceding text. The purpose of the search was to gather the most relevant and up to date information on geological, ecological, environmental and technological aspects as a reference for those working to assess the feasibility of the energy resource. The references were obtained from extensive library research, computer literature files and by contact with several agencies in both Texas and Louisiana who had an interest or could supply information on geothermal activities.

Accompanying annotations are from a variety of sources. These include author's abstracts, annotations from Campbell and Lehr (1973), the Second United Nations Symposium (1975), and extensive use of computerized literature files including AGRICOLA, BIOSIS PREVIEWS, COMPENDIX, ENVIROLINE, GEOREF, NTIS, POLLUTION ABS, SCISEARCH, and SOCABS, in addition to our own synopses of papers.

As an aid to use of the bibliography, a subject index has been compiled. Citations with information pertaining to each of the categories are listed by the numbers assigned to them in the annotated bibliography section.

1 Adams, S. M., 1976, The ecology of Eelgrass, Zostera marina, fish communities. II. Functional analysis: Jour. Exp. Mar. Biol. Ecol. 22, v. 22, p. 293-311.

Consumption, production and respiration of fish communities utilizing Eelgrass beds in a shallow estuarine system on the coast of North Carolina were estimated for 1971-1972; annual production was 21.7 kcal/m^2 in each bed with Pinfish accounting for 45 and 68% of the production in the two tested beds. Annual community respiration was 57.9 and 69.7 kcal/m^2 in the two beds with Pinfish accounting for 62.6 and 26.7% of the total in these beds. Estimation of the annual food energy consumed by Eelgrass fish community using the Winberg and daily ration methods gave values within 6% of each other.

Energy turnover was high, and efficiency of energy dissipation low for the Eelgrass fish communities, suggesting that resident fish populations were adapted to the temperature extremes within the bed. High ecological efficiencies and the high overall efficiency of the Eelgrass beds are efficient systems for converting consumed energy and solar radiation into fish.

2 Adams, S. M., 1976, The ecology of Eelgrass, Zostera marina (L.), fish communities. I. Structural analysis: Jour. Exp. Mar. Biol. Ecol., v. 22, p. 269-291.

Fish populations utilizing Eelgrass beds in two different estuarine areas of the North Carolina coast were analysed and compared to determine aspects of their community structure. The fish community of the Eelgrass beds were characterized by low diversity and high standing crops of biomass and energy, both of which showed seasonal variation. Wide temperature fluctuations related to the overall shallowness of the beds probably regulated the diversity of fishes utilizing the beds. This community was dominated by Pinfish which comprised 45% and 67% of the fish biomass of the two beds.

Changes in total body caloric content were probably related to developmental stages and changes in diet. Adult fish often had significantly higher weight-specific caloric contents than juvenile fish. Monthly or seasonal variations in caloric content of the organic matter of Pinfish had little influence on the caloric content within the various sizes of Pinfish.

There was a significant correlation between fish biomass, temperature and Eelgrass biomass. Fish biomass was highest when temperature and grass biomass were at a maximum. In general, water depth over the beds had little effect on the standing crop of fish within the bed, but cooler waters which occurred at night, darkness, or both, had a large effect.

3 Adelman, I. R., and Smith, L. L., Jr., 1970, Effect of hydrogen sulfide on Northern Pike eggs and sac fry: Trans. Amer. Fish. Soc., v. 99, no. 3, p. 501-509.

H_2S concentrations between 0.014 and 0.018 ppm for eggs and 0.004 and 0.006 ppm for sac fry were found to be the maximum safe levels. Eggs subjected to H_2S resulted in increasing percentages of sac fry with anatomical malformations. Sac fry hatched from eggs held at higher concentrations than the safe levels showed decreased growth rates. Reduced survival and decreased length were also observed for eggs and sac fry above the safe concentration levels.

4 Ahr, W.M., Daubenspeck, J., Harry, H.W., Littleton, T.G., Holliday, B., Miloy, J., and Vetter, L., 1973, Resource evaluation studies on the Matagorda Bay area, Texas: Texas A&M University Sea Grant Publication no. TAMU-SG-74-204.
Discussion of the water circulation patterns of Matagorda Bay and how these patterns affect processes such as coast line changes and pollution dispersal. Attempts to determine chronic pesticide and PCB levels of bay sediments and the physical-chemical variables that govern distribution and retention of chlorinated hydrocarbons in the sediments. The occurrences and distributions of selected benthic microfauna are considered in terms of the value of data on microfaunal populations as a means of elucidating processes of coastal change, pollution and water circulation. The economic structure of the Matagorda Bay area is discussed with considerations of how changes in population, resources, and transportation may affect the future economic structure.

5 Aidlin, Joseph W., 1975, United States law as it affects geothermal development, in Second United Nations Symposium on the Development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, p. 2353-2358.
Federal and State laws have inhibited the rapid development of geothermal energy. Although the Federal Geothermal Steam Act of 1970 became law in December 1970, it was not until 1974 that competitive lease sales were held on Federal lands, and only now are noncompetitive leases being issued or scheduled for issuance.

The many legal requirements, obstructions, and limitations have made the task for the limited number of persons charged with responsibility to accelerate geothermal development difficult and time consuming. For example, the requirements of the National Environmental Protection Act, the authority exercised by the Office of Management and Budget and the Internal Revenue Service, and the requirements of various government agencies such as the Forest Service have all contributed to the delay. Above all, there has not been, until recently, an overriding priority granted to geothermal development.

Various states have defined geothermal resources in their own ways; in so doing they have in many cases raised issues concerning the character and ownership of the resource. The resulting confusion has inhibited development.

6 Aldrich, D. V., Wood, C. E., and Baxter, K. N., 1968, An ecological interpretation of low temperature response in Penaeus aztecus and P. setiferus postlarvae: Bull. Mar. Sci., v. 18, no. 1, p. 61-71.

Postlarvae of the two species were tested under varying temperatures under controlled conditions. P. aztecus burrowed as the temperature fell to 12-17C and emerged as it rose to 18-21.5C. Under identical conditions, P. setiferus showed neither type of behavior. Differences are attributed to the seasonal arrival times of the two species in Gulf bays (P. aztecus arriving during the cold months, and P. setiferus during the summer).

The laboratory temperatures which stimulated burrowing in P. aztecus were comparable to those occurring naturally in the Texas and Louisiana coasts during the winter. The temperature range that stimulated emergence is similar to that which is associated with the appearance of the postlarvae in the bays. The data support the idea that postlarvae P. aztecus hibernate in the burrowed condition for at least a portion of the winter in the Gulf of Mexico.

7 American Fisheries Society, 1966, A symposium on estuarine fisheries: Trans. Amer. Fish. Soc., suppl. to v. 95, no. 4, Spec. Pub. no. 3, 154 p.

A publication of a symposium on estuarine fisheries presented at the 94th annual meeting of the American Fisheries Society at Atlantic City, New Jersey, September, 1964. The presentation is divided into four sections with 17 papers under the headings of: (I) The Estuarine Ecosystem; (II) The Estuary as a Habitat for Fishery Organisms; (III) Man's Impact Upon the Estuarine Environment; and (IV) Fishery Management in Estuarine Areas.

8 American Petroleum Institute, 1960, Subsurface salt-water disposal: Dallas, Texas: Am. Petroleum Inst., Div. Production, Vocational Training Series, Book 3, 92 p.

A handbook reference on the design, installation, operation, and maintenance of subsurface salt-water disposal facilities. The chapters include information on planning for subsurface disposal, gathering systems, treating plants and injection facilities, disposal wells, and economic considerations.

9 Amstutz, R. W., and Reynolds, L. C., 1968, Is the Earth's crust going to waste, II, Types of fluids injected and treating procedures: Natl. Petroleum Refiners Assoc., Mid-Continent Regional Tg., Wichita, Kansas, June 12-13, 1968.

Discusses the problem of organic growths in disposal well systems, especially in liquids stored or passed through open ponds.

10 Andersen, S. O., 1975, Environmental impacts of geothermal resource development on commercial agriculture: A case study of land use conflict: Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, p. 1317-1321.

This paper examines the probable impact of actions of increasingly well-informed landowners who negotiate for higher lease returns and stronger environmental protection. The environmental implications of geothermal development are summarized from the private landowners' perspective, the probable influence on lease provisions was investigated and there is an exploration of some of the corporate and social implications of these actions.

11 Andersen, S. O., and Wallace, L. T., 1976, The benefits and costs to land-owners from geothermal resource lease and development: Div. of Agri. Sci., University of California, Bull. no. 1876, January 1976, 27 p.

Topics covered include: 1) Using land for geothermal development, 2) effects on land of geothermal development, 3) ameliorating undesirable effects, 4) legal issues, 5) the geothermal lease, and 6) a conclusions section. The paper also contains information on noise, air pollustion, climatic modification, and water pollution. Subsidence and seismic influences, visual impacts and synergistic effects are also considered. Contains an extensive bibliography.

12 Angelovic, J. W., and others, 1976, Environmental Studies of the South Texas Outer Continental Shelf, 1975: vol. 1, Plankton and Fisheries Investigations, 162 p., 40 figs., basic data in appendicies A-F; vol. 2, Physical Oceanography, 290 p., 174 figs.; A report to the U. S. Bureau of Land Management prepared by the National Oceanic and Atmospheric Administration: National Marine Fishereis Service and National Ocean Survey, Washington, D. C.

Volume I contains baseline information for the waters of the Gulf of Mexico over the continental shelf off the South Texas coast on specific marine parameters prior to mineral exploration. Includes identification of the various components of the zooplankton and determination of seasonal and areal distributions and abundance with specific emphasis on shrimp larvae and ichthyoplankton. Research on the adult fish and crustacean populations within the study area included analyses of historical data on groundfish and shrimp as well as newly generated information on pelagic fishes and those of recreational importance. Assessment of pelagic and recreational fish species was conducted through hydroacoustical surveys, periodic sampling with gill nets, and creel surveys. Available historical hydrographic, water movement, and meteorological data have been analyzed to derive as comprehensive a picture as possible of physical oceanographic conditions in the South Texas lease area. (in volume II).

13 Anon, 1963, Water resources study Bayou Teche and Vermilion River, Louisiana: Public Health Service, Dallas, Texas, Division of Water Supply and Pollution Control.

The report indicates the water requirements for municipal, industrial and water quality control purposes to the year 2020 in the Bayou Teche and Vermilion River basins. Estimates are made of the benefits attributable to the federally constructed works which will provide water for these purposes.

14 Anon, 1971, Oso Creek technical assistance study, Preliminary study on the problems and opportunities for development of Oso Creek and Oso Bay, Coastal Bend Regional Planning Commission, Corpus Christi, Texas: Department of Housing and Urban Development, Wash., D. C. 13 p.

There are many factors which should influence any plan for development of Oso Creek. Flood control measures may be proposed for the Oso by the Corps of Engineers, Nueces County Drainage District No. 2, and the Nueces County Development Group. When agreement is reached concerning coordination of flood prevention and control for the upper Oso, then consideration must be given to the development plans for the entire Oso Creek basin. Existing and potential urban-industrial, extractive and agricultural contaminants must be identified and dealt with, i. e., sewage, brine or pesticides. Decisions must be reached concerning control of urban development within the Oso flood plain. As an estuary, the delicate ecological balance of the Oso must be maintained. A determination must be made in the near future as to the part Oso Creek will play in the development of Nueces County and the region.

15 Anon, 1973, Estuarine pollution, A bibliography: Office of Water Resources Research, Wash., D. C., Water Resources Scientific Information Center., 510 p.

The bibliography, containing 324 abstracts and references, is another in a series of planned bibliographies in water resources to be produced from the information base comprising Selected Water Resources Abstracts (SWRA). At the time of search for this bibliography, the data base had 50,631 abstracts covering SWRA through December 15, 1972. The report contains an author index and extensive subject indices.

16 Anon, 1973, Shell dredgingin San Antonio Bay, Texas, Volume II, Appendix A1 through B9: Army Engineer District, Galveston, Texas.

The second volume contains information on shell dredging subbottom, regulations, the industry, climatology, and sedimentation.

17 Anon, 1973, Research to determine the environmental response to the deposition of spoil on salt marshes using diked and undiked techniques: Skidaway Institute of Oceanography, Savannah, Georgia, 196 p.

The second year's studies included: water quality changes in relatively polluted areas during dredging; the effects on water quality of dredge spoil impoundment; processes responsible for water quality changes during dredging and after dredge spoil disposal; significant sediment parameters which can be measured that would give some basis for predicting water quality changes during dredging; dredging effects on fish and macroinvertebrates; and effects of dredging on benthic infaunal populations.

18 Anon, 1975, An interdisciplinary study of environmental pollution by lead and other metals: Illinois University at Urbana-Champaign, Institute for Environmental Studies, 97 p.

The study is based on the concept of a wide-scale, interdisciplinary project on environmental contamination by lead. The progress report for the University of Illinois Metals Task Force includes reports from the plant response, urban dust, synthesis and modeling, and analytical laboratory groups. The major objectives of the Metals Task Force are: (1) the development of interdisciplinary research methods on a university campus; and (2) an evaluation of the input, distribution, and effects of lead in the environment. Completed during 1975 are studies of the current distribution of lead in ecosystem components resulting from the use of lead in gasoline as well as a number of studies of the fluxes, and the effects of lead on ecosystem components other than man. The results are presented in the ecosystem group completion report. During the past year, investigations have focused on two areas: (1) lead effects on terrestrial plant productivity; and (2) sources, transport pathways, and forms of lead in the urban environment.

19 Anon, 1975, Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians: National Water Quality Laboratory, Duluth, Minn., 68 p.

Four detailed methods for conducting acute toxicity tests with freshwater, estuarine, and marine fish, macroinvertebrates, and amphibians are presented in an integrated format. Nomenclature is consistent with that used in other branches of toxicology. Concepts incorporated into the methods are applicable to toxicity tests with most aquatic organisms.

20 Anon, 1976, Handling and using dredged material: Environ. Sci. Technol., v. 10, p. 326-327.

The author points out that some violence has been done to the aquatic environment by dredging and filling operations. Dredging of navigable waters of the U.S. has required a Corps permit under the River and Harbor Act of 1899, but such permits were generally granted when it was deemed that no impairment of navigation would ensue. In 1958, the Corps began to examine dredging permit applications with somewhat more environmental scrutiny. The National Environmental Policy Act (NEPA, 1969), 1972 water pollution laws (P. L. 92-500), and 1973 ocean dumping laws (P. L. 92-532) provide that the Corps must carefully weigh environmental, as well as economic and navigational factors in any decision to grant, delay, or deny a dredging permit. The corps' power to deny a dredging permit has also been established in the courts. A landmark case (1969) involving a proposed mobile home park on Boca Ciega Bay, Fla., known as the Zabel v. Tabb case, helped to establish this power.

21 Anspaugh, L. R. and Phelps, P. L., 1976, An overview of the Imperial Valley Environmental project: Report by Lawrence Livermore Laboratory for the Energy Research and Development Administration, 11 p.

An overview of the Imperial Valley Geothermal Project to determine the environmental quality of the valley. Contains an in depth discussion of each of the seven main study sections: air quality, water quality, ecosystem quality (soil, plants, animals, etc.), subsidence and induced seismicity, health effects, socio-economics, and an integrated assessment.

22 Antia, N. J., Cheng, J. Y., 1975, Cultural studies on the effects from borate pollution on the growth of marine phytoplankters: Jour. Fish. Res. Bd. Can., v. 32, p. 2487-2494.

The autotropic growth of 19 species of marine phytoplankters, from 10 classes of algae, was tested on axenic cultures with boric acid additions of 0-100 mg/liter B to a nutrient-enriched, pH-controlled seawater medium. The results predict that, in the absence of stress from nutrient deficiency and pH adversity, inorganic borate pollution would be facilely tolerated by phytoplankton up to 10 mg/liter B: higher borate concentrations up to 100 mg/liter are expected to cause species redistribution tending to favor growth of some forms by suppressing that of others.

23 Armitage, K. B., 1972, Environmental physiology of freshwater planktonic crustacea: Kansas Water Resources Research Institute, Manhattan, 25 p., (NTIS: PB-208 023).

The addition of heated effluents to fresh water environments could affect ecosystem energetics by its effects on metabolism. The poikilothermic planktonic crustaceans presumably have a temperature-dependent metabolism. However, metabolic compensation could markedly modify the metabolism-temperature (M-T) curve and hence, the energy budgets of fresh water ecosystems. Four species of Daphnia were cultured at 10C and 20C. Their metabolism was measured at 10 - 12C and 20 - 22 C. D. pulex, D. similis, D. ambigua, and D. galeata mendotae showed some degree of metabolic compensation. Those animals acclimated at 10 - 12C had higher metabolic rates at 10 - 12C than animals acclimated at 20 - 22C. In most instances, metabolism at 20 - 22C was higher in the daphnids acclimated at 10 - 12C. R-T curves were determined for D. ambigua and D. galeata mendotae at five-degree intervals from 5C to 30C. The curve of D. ambigua acclimated at 10C clearly was shifted to the left (translation) of the curve for 20C acclimation. D. galeata mendotae showed little acclimation over the temperature range of 10 - 20C. Possibly a combination of rotation and translation occurred. D. galeata mendotae were grown from neonates at 10C and 20C. There was no difference in the size of the animals at which eggs first appeared, but animals at 20C began reporduction several days earlier and produced more young than animals at 10C. There was some evidence that the temperature at which eggs developed influenced subsequent growth and reproduction.

24 Armstead, H. C. H., 1975, Some unusual ways of developing power from a geothermal field (abs.), in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-3.

The conventional way of generating power from a geothermal field is by means of condensing turbines supplying base load. Non-condensing plants (apart from serving as pilot and emergency plants, and from their enforced use when generating base load from geothermal steam having a high gas content) could be used economically, and to a limited extent, for supplying secondary peak loads -- i.e., low load factor load 'below' the extreme peak in the load duration curve. An unconventional, but logical approach to cost analysis shows that exploration costs should be regarded as a variable, rather than as a fixed, component; and this conclusion supports the arguments in favor of using non-condensing plants for carrying secondary peak loads. With 'wet' geothermal fields sited above sea level, the water phase -- preferable after as much heat as possible has first been extracted from it -- may sometimes be able to contribute substantial by-product power by passing it through conventional water turbines. This by-product power could be used for base load, for peak loads, or even for augmented peak loads (pumped storage).

25 Army Engineer District, Galveston, Texas, 1973, Shell dredging in San Antonio Bay, Texas. Volume II. Appendix A1 through B9: Army Engineer Distric, Galveston, Texas (NTIS: EIS-TX-73-1799-SET).

The second volume of a five-volume series contains information on shell dredging, subbottom, regulations, the industry, climatology, and sedimentation.

26 Army Engineer Waterways Experiment Station, Vicksburg, Mississippi
1976, Dredged material research. Notes, news, reviews, etc., Volume D-76-8: Army Engineer Waterways Sta., Vicksburg, Miss, 6 p. (NTIS:AD-A034 678/3WP).

The major section in this note described work unit 4E02, designed to test the efficacy of establishing seagrass meadows on dredged material placed in subtidal situations. As a part of 4E02, Shoal Grass was transplanted from one location in St. Joseph Bay, Florida, to a barren dredged material substrate nearby. The article describes newly initiated Task 4E: Aquatic Habitat Development. Also included is a brief discussion of interim guidelines published for implementation of section 404(b)(1) of Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972).

27 Arnold, E. L., Jr., Wheeler, R. S., and Baxter, K. N., 1960, Observations of fishes and other biota of East Lagoon, Galveston Island: Spec. Sci. Report, U.S. Fish and Wildlife Service, no. 334, 30 p.

From November 1953 to May 1958, collections of biological material by plankton net, cast net, and dip net were made in the vicinity of the mouth of East Lagoon, Galveston Island, with emphasis being placed on the seasonal occurence and abundance of fishes. Results of these collections, coupled with visual observations, are presented and discussed. Thirty-five families of fishes were found to occur, dominated by the Clupeidae, Engraulidae, Sparidae, Scianidae, and Mugilidae. Concurrent water temperature and salinities are presented in tabular form.

28 Arnorsson, S., Ragnors, K., Benediktsson, S., Gislason, G. and Thorhallsson, S., 1975, Exploitation of saline high temperature water for space heating (abs); in Second United Nations Symposium on the Development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, Abstract volume, VIII-1.

Pilot plant tests carried out in the Svartsengi high-temperature area, SW Iceland, show that direct heating of fresh water with steam derived from the saline 235°C water yields hot water with good qualities for space heating and domestic use. The fresh water is heated to 110-120°C and flashed at 1 atmosphere pressure to degas it. During degassing, O_2 that was originally in the fresh water is removed, and CO_2 and H_2S, which are derived from the steam, are substantially lowered. At the same time the pH is raised. Other heat exchange methods were tested but the direct heating method is no doubt most economical and technically the superior. Flashing of the heated water in steps would still improve the effective energy utilization. It is the chemical composition of the

the steam and fresh water respectively, that determine the quality of the heated water, and the extent of the degassing. It seems likely that the direct heating method could be applied generally when the otherwise unsuitable geothermal fluids are intended for space heating. Exploitation of the saline high-temperature water in Svartsengi for space heating is planned. The estimated energy consumption is 110 MW(thermal). Exploratory drilling has been completed and four wells are avilable with a total capacity of 70-80 MW.

29 Atherton, R. W., Finnemore, E. J., Gillam, M. L., DeGance, A. E., Grimsrud, G. P., and Schainker, R. B., 1976, The analysis of subsidence associated with geothermal development: Natl. Sci. Found. Research Grant AER75-17298, Systems Control, Inc., Handbook, v. I, 250 p.

This document is designed to serve as a concise reference for the evaluation of potential land subsidence resulting from the development of geothermal resources. Its contents will be useful to those interested in land subsidence and its environmental impacts, and to those who are involved in developing geothermal resources.

The handbook is divided into two parts: (A)"A Primer on Subsidence and Geothermics", which provides an overview of the areas of information important to understanding subsidence and geothermics, and (B)"Subsidence Evaluation Procedures", which presents procedures for the evaluation of subsidence potential such as subsidence prediction techniques, an analogy method for evaluating subsidence, quantitative analysis methods for evaluating reservoir models, and operating policies for the mitigation of subsidence. Some useful tables and figures deal with direct subsidence impacts; compression tests on clay, silts, and sands; comparion of petroleum subsidence areas, including information on Goose Creek, Texas; comparison of ground water subsidence areas with information from the Houston-Galveston, Texas and Baton Rouge, Louisiana areas; and factors tending to influence geothermal subsidence.

30 Atlas, M., Schofield, E. A., Morelli, F. A., and Cameron, R. E., 1976, Effects of petroleum pollutants on arctic microbial populations: Environmental Pollution, v. 10, p. 35-43.

Microorganisms encounter oil in the Arctic from natural seepages and accidental spillages. Incubation of Prudhoe crude oil with water from coastal ponds along Prudhoe Bay resulted in several changes in the microbial communities. Bacterial populations increased by several orders of magnitude; amoeboid protozoa were replaced by flagellated protozoa; coccoid green algae completely disappeared; diatoms increased and blue-green and green filamentous algae appeared to be unaffected. The microbial populations associated with a natural oil seepage at Cape Simpsom were markedly different from those of the adjacent areas.

The seep was devoid of vascular plant cover and, in some areas, of bacteria. Fungi were found to be abundant in the bacteria-free regions. Lichen flourished in the older sections. Underlying oil slicks experimentally floated in Prudhoe Bay, the bacterial population increased in large part attributable to oil-degrading Pseudomonads, but species diversity appeared to be unaffected.

31 Atwater, G. I., and Miller, E. E., 1965, Effect of decrease in porosity with depth on future development of oil and gas reserves in South Louisiana (abs.): New Orleans, Louisiana, Am. Assoc. Petroleum Geologists Mtg. Abstracts and Programs.

Geologists and engineers have stated that the amount of gas in place per unit volume increases at greater depths because of the attendant higher reservoir pressures. To test the validity of this premise, the effect of depth of burial upon the other variables in the standard formula used to calculate the amount of oil and gas in place was studied.

Sandstone porosity data were obtained from more than 13,000 core samples, including samples from 101 fields in south Louisiana. A curve constructed from the data demonstrates that the amount of void space per unit volume available for the accumulation of oil and gas decreases with increasing depth. This decrease in porosity, which is 1.265 percent of total volume per 1,000 feet of burial, is the most important single factor controlling the amount of oil or gas in place per unit volume of sandstone reservoir rock.

Porosities associated with abnormally pressured reservoirs were studied, as well as the incidence of abnormally pressured reservoirs in south Louisiana as a function of depth of burial. The porosities of the abnormally pressured reservoirs, averaged by 1,000 foot depth increments, fit a straight line plot of porosities from all reservoirs.

It appears to be a reasonable hypothese that the observed decrease in sandstone porosities with depth is the mechanism creating the abnormal pressures so frequently encountered in oil and gas reservoirs of south Louisiana.

32 Aud, B. W., 1975, Reflection seismic techniques locate geopressured geothermal anomalies, in Dorfman, M. H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 133-144.

Interpretive techniques for predicting abnormal pressure and relative lithology from velocity analysis of seismic data are outlined. By use of correlations between high temperature and abnormal pressure zones, these techniques can be applied to the exploration of geopressured geothermal anomalies.

33 Austin, A. L., 1974, Lawrence Livermore Laboratory geothermal projects: Geothermal Power Development Conference, Proc.

The LLL geothermal development project emphasizes the development of methods for the recovery and energy conversion of high temperature, high salinity brines. The construction and operation of a small (@10mw/sub e/) field experimental power plant is planned to demonstrate the technical and economical feasibility of the methods, and to provide a continuing source of operating data useful for the design of larger commercial size systems. The binary cycle system and the total flow system are currently under development. A program for the recovery and utilization of geopressured resources is also under development.

34 Austin, A. L., 1975, Prospects for advances in energy conversion technologies for geothermal energy development (abs); in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May, 1975, Abstract volume, VII-6.

As a result of the increasing need for alternate energy supplies, there is considerable interest in accelerating the development of geothermal energy, particularly hydrothermal (water dominated) resources. Since temperatures of these water deposits are relatively low, thermo-dynamic constraints lead to inherently low recovery and conversion efficiencies which ultimately may limit economic incentives for development. Considerable information has been generated over the past fifteen years relative to existing hot water geothermal systems, and this data now comprises the conventional wisdom for evaluating the potential and viability of future geothermal developments. Since conversion systems will be a major factor influencing the future of geothermal energy, it is timely to attempt an assessment of possible new directions. The purpose of this paper is to examine the prospects for advances in energy conversion technologies, current status, and to comment on future research needs as they are currently perceived. The discussion will emphasize systems uniquely suited for hydrothermal resources, and will focus on the technical aspects. No attempt will be made to produce explicit economic evaluations since future costs, material availability, and financial factors are speculative at best, but more importantly any serious economic analysis must start with detailed designs which do not now exist. Instead, the paper will attempt a broader view of advanced concepts, and an assessment of the potential and problems of each.

35 Austin, A. L., Higgins, G. H., and Howard, J. H., 1973, The total flow concept for recovery of energy from geothermal hot brine deposits: U.S. Energy Resources Devel. Adm., Lawerence Livermore Lab. UCRL-51366, 39 p.

This report describes a new method for producing electrical power from the energy stored in hot brine deposits. The method uses the total flow concept. Hot (300°C, 2200 psia at ~5000 ft.) brine is allowed to expand to the surface where the well head product contains 20% vapor by weight and ~560 Btu/lb at ~400 psia. This thermal energy is converted to kinetic energy by expansion of the mixture through a converging-diverging nozzle. The high velocity output is used to drive a modified hydraulic impulse turbine operating at ~3.5 in Hg (20°F). Theoretically, this method should produce 60% more power than other systems for the hot brine application. The basic advantage is that the total flow is used, allowing recovery of energy in the liquid that would otherwise be lost.

The proposed method is developed specifically for application to the brines of the Salton Sea geothermal area, where enough energy is stored to provide at least 100,000 MW electrical generation capacity for 20 years. Once developed, the proposed method will be applicable to other geothermal deposits.

36 Baker, L. and Beckert, H., 1972, A partial bibliography of the ecology and biology of the coast of the Gulf of Mexico with emphasis on the Louisiana coast: The University of Southwestern Louisiana, Research Series no. 15, Biology, 108 p.

Contains 983 references to published and unpublished material dealing with the ecology and biology of the Texas and Louisiana coastal marshes and estuaries.

37 Baldo, L., 1975, Waterwaste disposal in geothermal plants: Milano, Italy, ELC-Electroconsult, Via Chiabreara 8.

The paper examines, from a technical and economical point of view, the problems of wastewater disposal in geothermal fields. The wastewater represents, particularly in hot water fields, a large portion of the total geothermal fluid. The main problems involve the active silica dissolved in the geothermal fluid, which tends to scale the ducts, and with the other dissolved salts (borates being the most noxious), which may pollute surface waters.

The disposal systems used in various geothermal fields or those proposed are: disposal into the sea by long ducts, re-injection, evaporation ponds, and storage basins to allow the discharge into rivers during the rainy season.

The choice of the most suitable solution requires carrying out a specific program of studies in the earliest stage of development of a new geothermal field.

38 Balashov, L.S., and Krainov, S.R., 1975, Rare elements in thermal ground water (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume IX-1.

The utilization of thermal ground waters for energy purposes may prove to be more profitable when using these waters as a source of obtaining lithium, rubidium, cesium, boron, strontium, etc. High concentrations of lithium, rubidium, cesium and boron have been found in thermal carbonic-dioxide water of mountain-folded regions of the Alpine zone, in thermal water of the regions of recent volcanism and in hot brines of artesian basins. High concentrations of strontium are characteristic only of artesian brines. Rare elements are accumulated mainly in sodium-chloride and calcium-chloride ground waters. Low values of the Na/Li, K/Rb and K/Cs ratios are typical of rare-metal waters. These ratios may be an exploration index of thermal water. The problem of industrial extraction of rare elements from thermal water should be developed in the direction of: (a) preparing a raw material base, i. e. finding thermal water and calculating water resources; (b) working out technological methods of extracting rare elements from thermal water of different geochemical classes.

39 Barlow, A. C., 1971, Basic disposal-well design, in Cook, T. D., ed., Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoir 18, Symposium Proc., Houston, Texas, December 6-9, p. 72-76.
Two factors, safety and utility, are basic in the design of disposal wells. Every means must be taken to insure the safety of the installation so that the environment is protected against inadvertent pollution. Also, the well must be designed for maximum utility so that continued disposal of the waste is assured. General features of disposal wells are discussed. Completions, casings, tubing and packer requirements, and safety precautions are considered.

40 Barnea, J., 1975, Multi-purpose geothermal resource development--an overview (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, IX-2.
Three interrelated complexes determine the possible multi-purpose utilization of a geothermal resource, namely, (a) the resource conditions (b) the regional economic conditions and (c) the institutional conditions. The resource conditions may allow hundreds of different resource combinations for multi-purpose utilization, depending on the type and size of the resource and its temperature, water, mineral and gas content, its balneological potential as well as nearby related resources. The regional economic conditions are overriding for resource utilization because most geothermal resources require local utilization. The detailed discussions lead to the conclusion that developed areas with agriculture, industries and cities offer the best conditions whereas rainy and sparesely populated tropical areas represent the most unfavorable economic conditions for multi-purpose geothermal projects.

Institutional conditions include government regulations on state and local level, the attitude of geothermal developers such as governments, oil companies, etc., environmental laws and attitudes and institutions providing geothermal training and information. It is shown that in almost all cases of government- owned geothermal projects, the de facto control is in the hands of government electricity corporations explaining the electricity-only utilization of most developed geothermal resources, an attitude shared by most oil companies, emerging as a main factor in the U.S. geothermal development. Paper sends with proposal for wider resource information, more economic studies and institutional improvements.

41 Barrett, B. B., and Gillespie, M. C., 1973, Primary factors which influence commercial shrimp production in coastal Louisiana: Louisiana Wildlife and Fisheries Commission Tech. Bull. no. 9, 28 p.

Considers the effects of temperature and salinity on the distribution and population success of Brown and White Shrimp. Seasonally the combined caused-effect relationships of rainfall and river discharge become dominant in population success and subsequent production. A correlation is noted between river discharge and shrimp production. Discusses the use of indices for predicting annual total Brown Shrimp production in Louisiana. The number of inshore surface water acres utilized as shrimp fishing grounds in coastal Louisiana varies from 2 to 2.85 million acres depending on salinity regimes. Between 1967 and 1972 the annual average inshore total production was 9.2 pounds of shrimp per acre based on the maximum fishing grounds of 2.85 million acres.

42 Bass, R. J. and Avault, J. W., Jr., 1975, Food habits, length-weight relationship, condition factor, and growth of juvenile Red Drum Sciaenops ocellata in Louisiana: Trans. Amer. Fish. Soc., v. 104, no. 1, p. 35-45.

Food habits of Red Rum were determined during the time the fish utilized a Louisiana salt marsh as a nursery area. Potentially available food organisms were sampled during the study. Includes a discussion of the changes in food with increasing fish size and differences between day and night feeding. The length-weight relationship, average coefficient of condition, and average growth rate per month were determined.

43 Bassi, D. E. and Basco, D. R., 1974, Field study of an unconfined spoil disposal area of the Gulf Intracoastal waterway in Galveston Bay, Texas: Texas A&M Univ. Dep. Div. Eng. Rep. COE-174, 74 p.

Dredge spoil obtained from maintenance dredging of the Gulf Intracoastal Waterway is presently disposed in unconfined, submerged spoil areas alongside the channel. Of interest, for economic and environmental reasons, is the dispersion of the spoil area with time. Grain size analysis of bottom sediment samples, depth soundings and wooden stakes were employed in field investigations to determine the approximate location of material from one such spoil area over a five-month period after disposal. Immediately following deposition, over 40 percent of the spoil (based on original in-channel volume) had left the designated spoil area and spread out over the bay floor primarily as a mud-density flow. Eventually spoil covered an area about three times larger than the original spoil area. Return of the spoil to the newly dredged channel did not appear significant during the study period primarily because of the predominant direction of tidal currents and due to the presence of a submerged dike along the channel. A brief summary of dredging and spoil disposal practices is also included.

44 Bebout, D. G., 1976, Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 2, Resource assessment: Univ. Texas, Austin, Center for Energy Studies, February 23-25, 44 p.

Subsurface techniques previously applied in petroleum exploration for locating and evaluating geopressured geothermal reservoirs are described and used to determine the extent and location of potential geothermal reservoirs along the Texas Gulf Coast. A potential reservoir should have a volume of at least 3 cu. mi., a subsurface fluid temperature (uncorrected) of at least 250°F., and a permeability greater than 20 millidarcies. The Gulf Coast geologic framework is outlined, and the character of Tertiary sedimentation is depicted by six electric-long cross sections normal to the Texas Gulf Coast. Data from the analyzed wells are tabulated and potential geothermal corridors are mapped. Subsurface techniques for locating geopressured geothermal reservoirs and site selection are also discussed.

45 Bebout, D. G., Agagu, O. K., and Dorfman, M. H., 1975, Regional sand distribution of the Frio Formation, South Texas: A preliminary step in prospecting for geothermal energy: in Dorman, M. H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 101-130.

A geologic study is made of the main sand trends of the Frio Formation. Three major Frio sand depocenters have been delineated; these are: (1) southeastern Hidalgo, western Willacy, and western Cameron Counties, (2) eastern Kenedy and Kleberg Counties, and (3) north-central Nueces County. Useful maps include net sand distribution, sand percentage, and isothermal maps based on electric log well data. The top of the geopressure zones and potential geothermal areas were delineated from correlations of these maps.

46 Bebout, D. G., Agagu, O. K., and Dorfman, M. H., 1975, Geothermal resources, Frio Formation, middle Texas Gulf coast: Univ. Texas, Austin, Bur. Econ. Geology Geol. Circ. 75-8, 43 p.

The geothermal resources of the Frio Formation in the middle Texas Gulf Coast are evaluated. At depths generally greater than 7000 ft., the sands and shales of the Frio Formation are overpressured and undercompacted. The insulating effect of these sediments results in the accumulation of subsurface heat, and as a result, high temperature water. The geopressured zone's resource consists of high temperature water of relatively low salinity and with dissolved methane gas. The following areas are investigated: depositional environments, the geopressured zone and its relationship to sand-shale distribution, growth faults, and fluid temperatures.

47 Bebout, D. G., Dorfman, M. H., and Agagu, O. K., 1975, Geothermal resources, Frio Formation, South Texas: Univ. Texas, Austin, Bur. Econ. Geology Geol. Circ. 75-1, 36 p., maps.

Due to the drilling of wells that have penetrated the Tertiary sediments, a geopressured zone containing high temperature fluids have been recognized along the Texas Gulf Coast. Limited data indicate that pore spaces within the sands in this zone are filled with water high in temperature, relatively low in dissolved solids, and saturated with methane gas. These waters are considered an important potential source of methane gas and thermal energy. A preliminary study of one of the two main sand trends (the Frio Formation), its sand distribution, and formation temperatures and pressures was undertaken to define prospective areas needing a detailed reservoir analysis prior to selection of a geothermal well site.

48 Bebout, D. G., Loucks, R. G., Bosch, S. C., and Dorfman, M. H., 1976, Geothermal resources, Frio Formation, upper Texas Gulf Coast: Univ. Texas, Austin, Bur. Econ. Geology Geol. Circ. 76-3, 47 p.

A geological appraisal of Gulf Coast Geothermal Resources, The Frio Formation is described, and major sand trends are identified in the upper Texas Gulf Coast. Maps and information are given for the structures, sand thickness and distribution, salt domes, and growth faults in the study area. Isothermal maps are constructed and location of the top of the geopressure zone and potential geothermal fairways are delineated. A list of the wells from which subsurface data were taken is included.

49 Bechtel Corporation, 1976, Conceptual design of commercial 50 MWe (NET) geothermal powerplants at Heber and Niland, California; San Francisco, Calif. ERDA, Division of Geothermal Energy, Bechtel Corp., #SAN-1124-1. (available from NTIS)

The report focuses on establishing the technical and economic viability of selected candidate energy conversion processes based on hydrothermal reservoirs that can be considered representative of a substantial percentage of the national resources. The report includes conceptual designs. corresponding capital cost estimates and engineering and construction schedules for two 50 MWe (net) commercial-scale geothermal power plants.

Part one describes a two-stage flashed-steam energy conversion process designed for the geothermal field at Heber, California, and part two describes the multistate-flash/binary energy conversion process employed at the Niland, California plant.

50 Bechtel, T. J. and Copeland, B. J., 1970, Fish species diversity indices as indicators of pollution in Galveston Bay, Texas: Contr. Mar. Sci. Univ. Texas, v. 15, p. 103-132.

Fish diversity indices were found to be useful indicators of environmental and pollution stress in Galveston Bay. Diversity ranged from 2.2 (Texas City, Galveston area) to 0.02 (in the Houston Ship Channel). Indications are that areas receiving the greatest amounts of effluent and toxic materials exhibit the lowest mean annual diversities. Sampling throughout the system indicated that the fish populations could be divided into somewhat separate communities, each structured to environmental and pollution stress.

Includes maps of sampling sites, dominant fish species for each season, species spawning during the study, species showing distinct migration patterns during the study. Also considers differences in measuring fish biomass and total numbers of fish.

51 Bella, D. A., 1975, Tidal flats in estuarine water quality analysis: Environmental Protection Agency, Ecological Research Series no. EPA-660/3-75-025, 186 p.

Considers general mixing processes and tidal hydraulics with special emphasis on the sulfur cycle as related to estuarine benthic systems. Sulfates are important because: 1) sulfides can influence the benthic oxygen uptake rate, 2) free sulfides are highly toxic to a variety of organisms, and 3) the release of hydrogen sulfide may contribute to a deterioration of air quality.

There is a high concentration of sulfur in saline waters as compared to freshwater. Field studies showed that estuarine waters can contain high concentrations of sulfides even when dissolved oxygen is present. There is an indication of a close relationship between the rate of sulfate reduction and the sulfate and soluble organic carbon concentration. Activities which could contribute to significant environmental changes within estuarine benthic systems were identified. Free sulfide within deposits was found at concentrations of 1 mg/liter in oxygenated tidal flats overlying high organic deposits. Free sulfide con concentrations of 50-100 mg/liter and higher can be found within the intersitial waters of high organic benthic deposits.

52 Bennet, F., Jr., and Jones, G. B., 1902, Survey of the Brazoria area, Texas: U.S. Dept. Agriculture, Soil Consev. Service, 25 p.
The general nature, climate, and agricultural conditions of Brazoria county in 1902 are described in addition to soil types. A general Soil Map is included.

53 Benson, W. A., 1976, Geothermal energy: A look into the future: Earth Sci., v. 29, no. 1, p. 22-27.
If 10% of the geothermal energy trapped in the upper 2 mi. of the earth's crust were extracted, it would provide 58,000 mw/yrs for 50 years. Vapor and liquid-dominated geothermal systems, geopressurized basins, hot and dry rock formations, and near-normal thermal gradient environments all have energy potential. Although geothermal energy has proved to be cost-effective, there are several implementation problems. The history of geothermal energy and factors that have spurred its recent development are summarized.

54 Berg, C. J., Jr., 1971, A review of possible causes of mortality of oyster larvae of the Genus *Crassostrea* in Tomales Bay, California: Calif. Fish and Game, v. 57, no. 1, p. 69-75.
Oysters of the Genus Crassostrea do not produce successive generations in Tomales Bay, California, because of the failure of the larvae to survive and set. Excessive turbidities, lack of proper food and blooms of dinoflagellates are probably the major causes of oyster larva mortality, although there are other contributing factors.

55 Bernard, W. J., 1975, Reservoir mechanics of geopressured aquifers, *in* Dorfman, M. H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 157-169.
To evaluate the practicality of producing energy from geopressured aquifers, methods to predict energy-production rates are necessary. This paper reviews established petroleum-reservoir engineering techniques as applied to geopressured systesm. Also, the effects of dissolved natural gas, shale water influx, and abnormally high rock compressibilities on aquaifer behavior are discussed.

56 Bernstein, L., 1967, Plants and the supersaline habitat: Cont. Mar. Sci. Univer. Texas, v. 12, p. 242-248.
Discusses survival capacity and growth of plants in relation to the effects of brine water discharge. Organisms may survive high salinities,

but suffer a retardation of growth. Methabolic processes may proceed at near normal levels even when cell division has been all but inhibited. Even though euryhaline littoral algae may survive high salinities, they may suffer lowered capacity for growth if the salinity is maintained at these levels for extended times. Sublittoral red algae are intolerant of salinities 1.5 times that of seawater. Many marine plants are sensitive to increases in salinity as small as 20%.

57 Biesinger, K. E., Lemke, A. E., Smith, W. E., and Tyo, R. M., 1976, Comparative toxicity of polyelectrolytes to selected aquatic animals: Jour. Water Pollution Control Fed., v. 48, p. 183-187.
The use of polyelectrolytes (that is polymers, flocculants, or coagulant aids) to control solids in potable water and municipal wastewater is widespread and increasing rapidly. Such substances are also being used extensively by food processing, textile, pulp and paper, fiber glass, glass and ceramic, paint, mining, metal and metal finishing, and petroleum industries for the recovery of certain products and the treatment of wastes. Polyelectrolytes are being sold by many companies in carload lots. There is concern about their effects on aquatic life because polyelectrolytes are used for water clarification before the discharge of wastes into natural waters. Very few studies have been made, however, to asses either the toxicity of polyelectrolytes to aquatic animals or their impact on the aquatic environment. The authors of the present study tested the acute toxicity of several polyelectrolytes to rainbow trout, lake trout (*Salvelinus namaycush,*) a mysid (*Mysis relicta*), a copepod (*Limnocalanus macrurus*), and a cladoceran (*Daphnia magna*) in Lake Superior water.

58 Blackwelder, P. L., Weiss, R. E., and Wilbur, K. M., 1976, Effects of calcium, strontium, and magnesium on the Coccolithophorid *Cricosphaera* (*Hymenomonas*) *carterae*. I. Calcification: Mar. Biol., v. 34, p. 11-16.
The effects of calcium, strontium, and magnesium on calcification and minerology of the calcified bodies of *Cricosphaera carter rae* were investigated. The ability of cells to calcify in various concentrations of these ions was examined following preliminary decalcification in CO_2. The percentage of calcified cells increased with increasing concentrations of Sr. Strontium added to the calcium-deficient media was much more effective than an equivilant concentration of Ca. Calcification was reduced in the absence of Mg. In low Mg concentrations, the coccoliths were 60% calcite and 40% aragonite, and in the absence of Mg, only calcite was formed.

59 Bleakney, J. W., 1972, Ecological implications of annual variation in tidal extremes: Ecology, v. 53, no. 5, p. 933-938.

Analysis of extreme tides in the Bay of Fundy, Canada, for the period 1899-1971, coupled with field observations, indicates the presence of a complex of environmental variables. Extreme tides expose organisms to a variety of stresses depending upon the time of the year and weather conditions; but as both weather and tidal extremes are acylic relative to the life span of short-lived species, there is no opportunity for genetic selection of suitable behavioral responses, such as those associated with seasonal changes in light and temperature. Consequently, eulittoral organisms, particularly those in the broad fringes such as salt marshes and mud flats, can be caught off guard at any stage of their life history. The destruction of bird nests and the stranding of fish are common examples.

60 Bloomster, C. H., 1975, Geocost: A computer program for geothermal cost analysis: Natl. Tech. Inf. Service, Rept. BNWL-1888, February 54 p.

The Geocost computer program, a simulation model that calculates the cost of generating electricity from geothermal energy, is described. Geocost can simulate the production of electricity from most types of geothermal resources. It is composed of two principal parts: a reservoir model that simulates the exploration, development, and operation of a geothermal reservoir; and a power plant model that simulates the design, construction, and operation of the power plant. Five different types of power plants can be simulated; these are flashed steam, binary fluid cycle, a hybrid combine flashed steam-binary fluid cycle, total flow, and geopressured reservoirs.

61 Boothby, R. N., and Avault, J. W., Jr., 1971, Food habits, length-weight relationship and condition factor of the Red Drum, Sciaenops ocellata, in southern Louisiana: Trans. Amer. Fish Soc., v. 100, no. 2, p. 290-295.

The main food items in order of occurence for adult Red Drum were fish, shrimp, and crabs. Blue crabs, mud crabs, and penaeid shrimp were the crustaceans most frequently eaten, and at least 14 different species of fish were utilized to some degree. Food habits varied substantially from season to season. Fish was the main food item during winter and spring months. Crustaceans, crabs and shrimp combined comprised the bulk of the diet during the summer and fall months. Only slight differences in food habits were detected due to size or sex.

Gonadal examination of adult fish in southeastern Louisiana indicated that spawning took place between September and December. The length-weight relationship and seasonal condition values were determined. Red Drum of a given standard length were generally heavier than previously reported. Condition values from this study represent fish in overall good condition.

62 Boyer, V. S. and Wiedersum, G. C., 1973, Cooling system options for power plants. The case for once-through cooling: Engineering aspects of siting and operating power plants, Seminar, Paper, Washington, D. C., February 13-14, 1973, 11 p. Published by Atlantic Industrial Forum, Inc., New York, 1973.

The amounts of heat that must be discharged from a nulcear power plant are large, and the author claims that a once-through cooling system is the preferable choice in many cases because it has the lowest cost, it requires the least space, it has little or no influence on aesthetics or the atmosphere, and it results in less net water loss, compared to alternates such as cooling towers or spray ponds. Careful design of intake and discharge structures and competent investigation of marine life in the vicinity can result in a minimum overall effect on the environment and a very favorable benefit-cost ratio. Some data from the 100 Mw Peach Bottom units on the Susquehanna River, and some of the measures taken there to protect the environment are mentioned.

63 Boulding, K. E., 1956, The image: knowledge in life and society: Ann Arbor, Michigan.

A deft analysis of the process by which ideas or "images" grow and change.

64 Brennan, J. J., Gates, D. G. and Carruth, C., 1976, Effects of water quality on the recreational use of water in southeast Texas. Report to the Office of Water Research and Technology, Washington, D. C., by Texas A&M University and Lamar University. (NTIS:PB-256 585/1ST).

The estuarine segment of the Neches River in Southeast Texas flows through the middle of a metropolitan area. It is under-utilized for direct contact, water-based recreation. A public opinion poll of the general populus revealed that 66% participated in swimming and/or skiing in lakes and streams in the region, however, only 45% of those had so used the Neches in the recent past. Of those who had used the Neches, 50% said they would not do so again. Reasons for these attitudes are explored and compared to measured water quality parameters. Another survey of people actually using the river was made. Their responses and attitudes were compared to measured water quality parameters. Effects on attitudes of historical, well-founded prejudices and media reports of recent violations are discussed.

65 Breuer, J. P., 1957, An ecological survey of Baffin and Alazan Bays, Texas: Pub. Inst. Mar. Sci. Univ. Texas, v. 4, no. 2, p. 134-155.

This survey was conducted from June 1951 to May 1953 and includes descriptions of the areas and stations, with historical background. Also considered are salinity and tides in relation to the biological components. Discussion includes vegetation, invertebrate as well as vertebrate components, with special emphasis on Mullet and baitfishes, Spotted Sea Trout, Redfish, and Black Drum. The physical and meteorological aspects of these bays are unique in that they have produced hypersaline conditions resulting in a faunal makeup different from other South Texas Bays.

66 Breuer, J. P., 1970, A biological survey of the tidewater areas of the Rio Grande. Coastal Fisheries Project Report. 1969-1970: Texas Parks and Wildlife Department, p. 127-140.

Hydrographic and biological sampling stations were established on the lower Rio Grande River between four miles and 28 miles upstream. Hydrographic samples included water temperature, salinity, pH, turbidity, and dissolved oxygen. Consideration is given to the contribution of the Rio Grande to the marine fisheries of the lower Laguna Madre. Determinations of relative abundance were made and checklists of vertebrate and invertebrate fauna are included.

67 Brown, L. F., Jr., Brewton, J. L., McGowen, J. H., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, Environmental geologic atlas of the Texas Coastal Zone--Corpus Christi area: Univ. Texas, Austin, Bur. Econ. Geology, 123 p. maps.

The Environmental Atlas of the Texas Coastal Zone is designed to provide an urgently needed inventory for this most vital area of Texas. Presented is information on the nature of the Coastal Zone, what is happening to it, and at what rate changes are taking place. The basic environmental geology map delineates and depicts in detail resource units of first-order environmental significance. The accompanying series of eight special-use maps is designed for particular information needs. Included are physical properties and land use suitability, current land use, active physical processes, mineral and energy resources, land and submerged land topographic and bathymetric configuartion, natural and artificial water systems, and climate. Statistical tables define and inventory the more than 250 natural and cultural features of the Texas Coastal Zone. A descriptive text explains the data presented, their utility, and means of extrapolating for other special uses.

Included in the map area of this volume are parts of Aransas, Bee, Jim Wells, Kleberg, Nueces, Refugio and San Patricio Counties, Texas.

68 Brown, L. F., Jr., Morton, R. A., McGowen, J. H., Kreitler, C. W., and Fisher, W. L., 1974, Natural Hazards of the Texas Coastal Zone: Univ. Texas, Austin, Bur. Econ. Geology, Spec. Atlas, 13 p., maps.

The principal natural hazards in the Texas Coastal Zone are 1) hurricanes, 2) flooding, 3) shoreline erosion, 4) land-surface subsidence, and 5) faulting. This atlas is composed of a series of Natural Hazards Maps and a text describing hazard distribution and occurrence, processes and causes, impacts, mitigation, and reduction. Most hazard-prone elements and areas are based on observed, historically documented information.

69 Brown, R. J., 1975, Salt Marshes (A bibliography with abstracts): National Technical Information Service, Springfield, Virginia, 97 p. (NTIS: PS-75/426/7ST).

Presented are citations dealing with all aspects of salt marshes. Most of the topics cover ecology, productivity, pollution effects, and land use effects. Contains 92 abstracts.

70 Brown, R. J., 1976, Salt Marshes (A bibliography with abstracts): National Technical Information Service, Springfield, Virginia, 165 p. (NTIS: PS-76/0439/OST).

Citations dealing with all aspects of salt marshes are presented. Most of the topics cover ecology, productivity, pollution effects, and land use effects. This updated bibliography containes 160 abstracts, 68 of which are new entries to the previous edition.

71 Bryan, C. E., 1971, An ecological survey of the Arroyo Colorado, Texas 1966-1969: Texas Parks and Wildlife Tech. Ser. no. 10, p. 1-28.

The lower portion of the Arroyo Colorado is one of very few brackish water areas in the Lower Laguna Madre of Texas and provides a nursery ground for marine species of the region. Organisms were sampled and an annotated list of organisms collected is presented. Data on biological and hydrographic conditions prior to and following a major flood were obtained. There was an inverse relationship between enroaching high salinity water and low dissolved oxygen readings, indicating high organic content and poor water circulation. Pesticide content in organisms was monitored, and every sample analysed contained DDT and most contained Dieldrin and Endrin. DDT and its metabolites have also been found in the water and sediments.

72 Bureau of Economic Geology, The University of Texas at Austin, 1970, Effects of Hurricane Celia- A focus on environmental geological problems of the Texas Coastal Zone. Geological Circular, 70-3.

Discusses hurricanes on the Texas coast and presents a model on their effects. Hurricane Celia is discussed in terms of effects on barrier islands: storm passes and washovers, beaches and dunes, and backland areas; effects on bays and adjacent areas; modification of storm effects by normal processes; and effects of storms on man-made features and structures. Includes a review of land-use planning in terms of future storms and recommendations.

73 Burk, C. J., 1976, A four-year analysis of vegetation following an oil spill in a fresh water marsh: Report to the Water Resources Research Center by the University of Massachusetts, Amherst, 46 p.(NTIS:PB-258/766/5WP).

Changes in the composition of vegetation occurring in a freshwater marsh were studied for four years following an accidental oil spillage. Total plant cover and diversity measured by species richness, mean species per quadrat, and the Shannon-Wiener function were progressively reduced in both high and mid-marsh zones for two years after the spillage. Eighteen of the species found before the spill were not found the season following. Perennial species tended to be less affected by the oil immediately following the spill than annual species.

74 Burst, J. F., 1969, Diagenesis of Gulf coast clayey sediments and its possible relation to petroleum migration: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 1, p. 73-93.

A discussion of dehydration and diagenesis of clay minerals due to burial and geothermal history.

75 Byars, H. G., and Gallop, B. R., 1972, Injection water and oxygen corrosion and/or well plugging solids: AIME, Soc. Petroleum Engineers, Handling of Oil Field Waters, Symposium, Los Angeles, California, December 4-5, 1972, paper no, 4253, p. 95-104.

Aeration of injection waters can create numerous problems. Corrosion of equipment, scale deposition, and injection well plugging can reduce the profitability of a waterflood by affecting the ability to get the correct volumes of water into the proper zones at the proper time for efficient sweep and recovery. Operation of a "closed", air-free system will minimize many of these problems.

Practical approaches to the successful operation of such systems involve design and operation of water sources, oxygen removal from aerated sources, and maintenance of oxygen-free conditions throughout the system. Day-to-day operation, monitoring techniques, and "oxygen conscious" personnel are important.

76 Cairns, J., Jr., Benfield, E. F., Buikema, A. L., Jr., Dickson, K. L., and Hendricks, A. C., 1976, Development of biological indices for identifying and evaluating impacts of pollutants on freshwater ecosystems. Annual Progress Report, June 1, 1975-February 28, 1976. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 50 p. (NTIS:ORO-4939-3).

The research represents an effort to devise and evaluate biological methods for determining the functional response of aquatic organisms to perturbations. The research effort fell into four general categories: structural and functional aspects of auto-and heterotrophic attached microbial communities in lotic systems with emphasis on carbon, nitrogen, and sulfur. The uptake of carbon, nitrogen, and sulfur under controlled and field situations was investigated along with biomass, ATP, and chlorophyll measurements, and the relationship of protozoan invasion and extinction rates to the eutrophication process. Protozoan invasion and extinction rates were measured under oligotrophic and eu= trophic conditions in numberous lakes and reservoirs. Behavioral responses of zooplankton subjected to cooling water entrainment were studied. Zooplankton were subjected to various conditons that would be encountered during entrainment. Detritus processing by macroinvertebrates was investigated as a pollution stress assessment technique. Organisms were exposed to measured units of detrital material and pollution stress through time; and their rates of processing were compared to processing rates of similar organisms that were not exposed to the stress.

77 Campbell, M. D. and Lehr, J. H., 1973, Water well technology: Field principles of exploration, drilling, and development of ground water and other selected minerals: National Water Well Association, McGraw-Hill Book Co., 681 p.

Textbook on shallow well technology covering ground water pollution; several aspects of drilling; borehole geophysics; and well design, construction, hydraulics and maintenance; and cost analysis. An annotated bibliography is included.

78 Carlson, R. A., Powell, P. H., and Underhill, G. K., 1976, Industrial utilization of geopressured geothermal energy, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, p. 139-181.

A discussion of the industrial utilization of geopressured geothermal energy with regard to specific potential resource zones in Texas. The Kenedy and Matagorda County zones are situated in rural areas with little or no industrial activity, and the Corpus Christi and Brazoria-Galveston zones are in and adjacent to highly industrialized and urban districts.

Proposed industries for geothermal fluid utilization were considered via two approaches: through a survey of existing industry with possible applications of natural geothermal fluids, and through consideration of upgrading the quality of existing geothermal fluids to meet an industry's fluid requirements.

Some industries discussed are: lumber and concrete products, kilning, secondary recovery of petroleum, make-up for coal slurry pipelines, power plant cooling lakes, agriculture, chemical industry, frasching in the sulfur industry, petroleum and natural gas pipelining, coal desulfurization and preparation, and uranium leaching, crushing and conveying.

79 Carlson, R. A., and Underhill, G. K., 1976, Net energetics analysis, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, p. 27-53.

Net energetics analysis, as applied to energy generation facilities, is a method for determining the total amount of energy required to construct, operate, and maintain the energy generation facility compared to the total energy generated (or converted) throughout the facility's lifetime. The net energetics analysis method has been reviewed and applied to four power plants--three geothermal plants and one coal-fired power plant. In addition, a geopressured geothermal methane production plant and a pressurized water nuclear power plant are compared.

The main conclusions are: 1) Utilization of the geopressured geothermal resource competes favorably, on an energetic basis, with western coal-fired and nuclear power stations sited in Central Texas. 2) Hot water resources located in sedimentary deposits at 5,000-9,000 foot depths, and not possessing reasonably high temperatures (>400 F) at the wellhead (flashing suppressed by pumping) will not compete, on an energetics basis, with western coal-fired or nuclear power stations in the same locality if methane is not present.

80 Carlson, R. A., and others, 1976, Industrial utilization of geopressured geothermal energy, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies.

A good summary of alternate uses of geothermal waters, especially in regard to specific locations of sites on the Gulf Coast (Rio Grande and Corpus Christi Region). A description of sulfur frasching, other utilization including petroleum and natural gas pipelining, coal desulfurization and preparation, uranium leaching, crushing and conveying, lumber and concrete products kilning, secondary recovery of petroleum, agriculture, makeup for coal slurry pipelines, and power plant cooling lakes. There is also a section concerning beneficiation of geothermal water.

81 Carpelan, L. H., 1967, Invertebrates in relation to hypersaline habitats: Contr. Mar. Sci. Univ. Texas, v. 12, p. 219-229.
Organisms in supersaline waters are discussed in terms of distribution and osmotic and ionic regulation. Brackish and supersaline waters are characterized by instability. The species able to survive these waters must be euryhaline, and thus often attain tremendous numbers. This type of environment is considered a transitional community, and generalizations cannot be made concerning productivity and utilization of energy within the ecosystem.

82 Carr, J. T., 1967, Hurricanes affecting the Texas Gulf Coast: Texas Water Development Board, Report no. 49, 58 p.
Along the Texas Gulf Coast, damage from high water caused by hurricanes and their heavy attendant rains has been greater than damage done by hurricane winds and hurricane-sprawned tornadoes combined. Because of wind set-up and the configuration and depth of Texas bays, hurricane-caused high water has been higher at the heads of bays and in estuaries than on the open beaches. Land subsidence in certain coastal areas of heavy groundwater and oil withdrawals has amounted to as much as 5 feet during the period 1905-64. Thirty-two hurricanes affected Texas during the period 1900-1965.

83 Carr, J. T., and others, 1965, Water supply limitations on Irrigation from the Rio Grande in Starr, Hidalgo, Cameron, and Willacy Counties, Texas: Texas Water Comm. Bull. 6413A, August, 138 p. (Available from Texas Water Devel. Board.)
These appendices are the reports on separate investigations and studies undertaken to obtain pertinent data and to develop bases for the selection of criteria for use in the comprehensive study summarized in the Texas Water Commission Bulletin 6413, "Water-Supply Limitations on Irrigation From the Rio Grande in Starr, Hidalgo, Cameron, and Willacy Counties, Texas," November 1964.

Individual studies cover the following topics:
Appendix I: Climate of the Lower Rio Grande Valley
II: Soils of the Lower Rio Grande Valley
III: Cropping Pattern of the Lower Rio Grande Valley
IV: Water Transmission Losses to Irrigators to the Lower Rio Grande Valley
V: Review of Reports of the United States Section, International Boundary and Water Commission, United States and Mexico, on the Hydrology of the Rio Grande, 1900-1956.
VI: Economic evaluation of Agricultural Water Use in Starr, Hidalgo, Cameron, and Willacy Counties.

84 Carter, W. T., 1910, Reconnaissance soil survey of the central Gulf coast area of Texas: U. S. Dept. Agriculture, 75 p., map.

The study area is composed of 12 counties; Brazoria, Matagorda, Calhoun, Aransas, Refugio, Bee, Goliad, Victoria, Jackson, Wharton, Dewitt and Karnes. A general description of the area as well as discussion of the major soils series is given. Information is also given on agriculture and irrigation practices at that time. Includes a general soil map.

85 Carver, R. E., 1968, Differential compaction as a cause of regional contemporaneous faults: Am. Assoc. Petroleum Geologists Bull., v. 52, no. 3, p. 414-419.

Regional contemporaneous faults occur on the inshore sides of major Gulf Coast depocenters and develop as normal faults with major negative displacements on the Gulf, or depocenter, side. The distribution and characteristics of the faults suggest that they are sediment-related and are caused by large differences in compaction of adjacent sediment masses - either as a result of change of thickness or of facies change.

A model was constructed to test the hypothesis that differential compaction could cause faulting in unconsolidated sediment.

86 Chalmers, A. G., Haines, E. B. and Sherr, B. F., 1976, Capacity of a Spartina salt marsh to assimilate nitrogen from secondarily treated sewage: Environmental Resources Center, Georgia Institute of Technology, Atlanta, 100 p. (NTIS:PB-258 640/2WP).

Secondarily treated sewage sludge was applied to duplicate 100 square meter plots in a Spartina high marsh near Sapelo Island, Georgia, at a rate of 200 g sludge, or 4 g nitrogen per square meter every two weeks for 12 months. Monthly measurements were made of nitrogen pools in the marsh plants and soils in the experimental plots and in duplicate control plots in high marsh and in low marsh areas. Potential denitrification rates were also analyzed for marsh soils in the study sites.

87 Chatwin, P. C., 1976, Some remarks on the maintenance of the salinity distribution in estuaries: Estuarine and Coastal Marine Science, v. 4, p. 555-566.

A set of model equations describing the time-average velocity and salinity in an estuary is discussed and used to obtain expressions for the longitudinal and vertical components of velocity and for the salinity distribution. The theory is shown to be self-consistent in the central part of the estuary and to be in reasonable agreement with observations reported by Harlemann and Ippen (1967). Finally it is argued that theoretical treatments of this problem which use a steady one-dimensional diffusion equation to describe the longitudinal salinity distribution are physically unrealistic.

88 Chiostri, E., 1975, Use of geothermal resources in the medical treatment of man (abs): In Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VIII-3.

The aim of geothermal resources is not only to provide energy and heat sources for the technical development of humanity. Curative properties in natural hot water have been through the centuries discovered to be the result of not only its temperature, but also to the physico-chemical properties of the salts and the gases dissolved in it. This water can be used for several treatments depending upon their composition: as a drink for nutritional diseases, for the stomach, the intestines, etc.; in the form of baths (often in connection with treatments with mud which is also natural) in arthritic and rheumatic affections: and in the form of inhalation for diseases of the respiratory system. The use of these natural treatments is especially important in the areas of preventive and mass medicine. Think of the imposing number of working days lost in the whole world because of a plague having a social scope like rheumatism which can be stopped or made less severe precisely by these natural treatments. It is proposed to the study committees on geothermal resources that the curative factor be given its place in the classification and the exploitation of these resources.

89 Chipman, R. K., 1959, Studies on tolerance of certain freshwater fishes to brine water from oil wells: Ecology, v. 40, no. 2, p. 229-302.

Several species of freshwater fishes are known to tolerate some degree of salt water. Information regarding this tolerance is scanty, and usually concerns the spontaneous entry of fish into saltwater. The purpose of this report is to present data showing to what extent certain freshwater fishes can tolerate saltwater in a habitat from which they cannot escape. This study was based on field data and a limited amount of experimental data. Previously published data on the tolerance of certain species are brought together in this report.

90 Chow, V. T., Csallany, S. C., Krizek, R. J., and Preul, H. C., eds., 1973, Water for the human environment: Champaign, Illinois, Internat. Water Resources Assoc., World Cong. on Water Resources, 1st Proceedings, Chicago, Illinois, 24-28 September 1973, 4 vol., 1987 p.

One-hundred-sixty-nine papers by various authors are presented. The topics discussed are: Global environment, water resources, energy, dams, warming, Arctic oil, coal mining and water, Ganges River Basin, water law, hydraulic grids, irrigation, pollution, international coordination, hydrogeology, interbasin transfer, integrated water resources development, ground water, floods, aquifers, measurements, sewage, storage, water resources in developing nations, desalination, hydrologic programs, information systems, wastewater reclamation, thermal pollution, cooling, systems analysis, hydrographs, watersheds, limnology, oxygen transfer, and water quality. Selected papers are indexed separately. In Spanish, French, German with English abstracts.

91 Cisneros, B., 1974, Coastal vegetation communities of two Texas barrier Islands, Boca Chica and Brazos: Masters Thesis, Pan American University, Edinburg, Texas, 45 p.

These Texas barrier islands have unique coastal vegetational communities that may be influenced by several environmental factors including temperature, precipitation, wind speed, sunshine exposure, day length, and dune height. The author attempts to determine the total number of coastal plant species per station, season, and year while considering the environmental factors that may significantly affect the number and pattern of coastal species. Coverage comparison between aerial and land sampling and aerial vegetational zonation was also considered.

92 Clark, H. L., Haley, G. J., Herbert, E. J., Hollier, R. M., Jr., and Roy, A. J., 1962, Soil Conserv. Service, Series 1959, no. 15, 57 p., maps.

The Soil Survey of Acadia Parish contains a general soil map and air photo coverage of the parish. Five soil associations are designated and the soil series within these associations are described. A section on use and management of soils outlines the principal problems of using the soils of Acadia Parish and gives some general practices to correct these conditions or adapt to them. Other sections are genesis, morphology and classification of soils, climate, native vegetation, and engineering properties of the soils.

93 Clark, J. R. and Turner, R., 1976, Barrier Islands: A threatened, fragile resource: Conservation Foundation Letter, August 1976, no. 12.

Barrier islands provide unique habitat and food for countless species of birds, mammals, and aquatic life. On the other hand, many barrier islands are targets of intense real estate speculation and development activity, fueled by national prosperity, easy transportation, and a growing scarcity of available waterfront recreation land. There is no national policy or commitment to save still unspoiled barrier islands. However, state designation of barrier islands and beaches as "areas of particular concern," and requirements for special review and restraints could go far toward protecting these ecologically fragile resources.

94 Clark, J. 1974. Coastal ecosystems: ecological considerations for management of the coastal zone. Washington, D. C., The Conservation Foundation, 178 p.

Environmental management of coastal waters and shorelands has as one of its fundamental goals the maintenance of coastal ecosystems in their best condition, or at the level of best achievable ecosystem function, which usually means as near to the natural condition as possible.

Whatever its specific goals may be an environmental management program must embrace whole ecosystems. Any attempt to manage separately one of the many interdependent components of a complex ecosystem will very likely fail. So would any attempt to control any one source of environmental disturbance to the system without controlling others. The ecosystem defined must embrace a complete and integral unit, one that includes a coastal water basin (or basins) and the adjacent shorelands to the extent they have significant influence on coastal waters.

Development adjacent to estuarine waters will require exceptionally vigorous management attention. For this reason Clark has given a higher degree of attention to estuaries than to ocean water areas.

95 Clark, S.H. and Caillouet, C.W., Jr., 1973, White Shrimp *Penaeus setiferus* population trends in a tidal marsh pond: U.S. Nat. Mar. Fish. Rev., v. 35, nos. 3-4, p. 27-29.

Estimations were made of initial population, rates of immigration, fishing, and other losses in a White Shrimp population in a Texas tidal marsh pond. The significant decline in catch rates of marked and unmarked shrimp during the experiment was due to fishing and other causes (emigration and natural mortality), but the reduction due to fishing was less than that due to other causes. The authors believe that the method used or similar methods offer considerable promise in future studies of this nature.

96 Clemens, H.P. and Jones, W.H., 1955, Toxicity of brine water from oil wells: Trans. Amer. Fish. Soc., v. 84, p. 97-109.

Median toxicity thresholds were determined for 10 species of fish and invertebrates in brine water from an oil well. Thresholds were expressed as percentage volume of the original waste since the brine contained large amounts of calcium, magnesium, potassium, and sodium as well as chloride ions. However, computations of hypothetical combinations of chlorides in the brine indicated sodium chloride to be present in such proportions as to be most toxic. The authors also discuss the antagonistic effects of calcium, magnesium, sodium, and potassium in the presence of chloride ion. The presence of these ions in brine wastes in high concentrations along with chloride ions creates important questions as to the effects of ion imbalances.

97 Cockerham, W.L., Dance, R.E., White, A.G., and Spicer, B.E., 1973, Soil Survey, St. James and St. John the Baptist Parishes, Louisiana: U.S. Dept. Agriculture, Soil Conserv. Service, August 1973, 50 p., maps.

The St. James and St. John the Baptist Parishes soil survey contains a general soil map and description of the soils and air photo coverage of the Parishes. Suitability of soils for several land uses is also given. Some of the land uses discussed are: agricultural, woodland and wildlife, and urban and recreational. Engineering characteristics are given as well as formation and classification of the soils and methods for sampling and analysis. There is a section giving general information about the Parishes.

98 Cole, R. A., Nalepa, T. F., Freeman, R. A., and Parkhurst, B. R., 1976, An ecological evaluation of thermal discharge: Parts I - V and summary, National Technical Information Service Report, no. PB-240 706-II, 1971-1973 (609).

The effects of a steam-electric power plant on the western shore of Lake Erie on the aquatic environment of the lake, including the distribution of phytoplankton, zooplankton, and several fish species near the shore, were studied. The distribution and dynamics of selected aquatic chemical and physical parameters near the western shore and the mouth of the Raisin River, which flows into the lake, are defined. According to the preliminary results of the studies, phytoplankton is resistant to the kinds of environmental stress imposed by municipal and industrial thermal discharges into the lake. The effects of the thermal discharge on the fish populations of Lake Erie are more complex and are reported in greater detail.

99 Coleman, J., Jr., 1966, Recent coastal sedimentation, central Louisiana coast: Louisiana State Univ., Coastal Studies Inst., Tech. Rept. no. 29, 73 p.

This paper discusses the Recent near-surface sediments of Vermilion, Iberia, and St. Mary Parishes, Louisiana. These sediments can be divided into 2 types: those sediments which were deposited by now abandoned Mississippi River distributaries and those carried along shore and deposited at the delta margin. Sedimentation and depositional events are described, starting with the oldest recognizable Recent Mississippi River delta, which was actively depositing sediments 4600 years ago. All existing facies are discussed and stratigraphic sections of the study area are constructed.

100 Collins, A. G., 1966, Here's how producers can turn brine disposal into profit: Oil and Gas Jour., v. 64, p. 27, 112.

Discusses a general plan for and against the salvage of minerals from oil-field brines. Such an operation may not result in profit for all producers, but precipitating such minerals in a brine-gathering system might be cheaper than providing brine disposal facilities in the field.

101 Collins, A. G., 1971, Oil and gas well--Potential polluters of the environment?: Water Pollution Control Federation Jour., v. 43, no. 12, p. 2383-2393.

Discusses potential of oil-gas well ground water pollution via drilling fluids, chemical treatment of oil-gas wells, oil industry corrosion inhibitors from products of oil and gas, and from oil industry waste disposal.

102 Conover, J. T., 1958, Seasonal growth of benthic marine plants as related to environmental factors in an estuary: Pub. Inst. Mar. Sci. Univ. Texas, v. 5, p. 97-147.
Seasonal factors affecting growth of marine benthic plants are included in this study. Although the study area was not the Gulf of Mexico, the data may be useful in making correlations since many of the species discussed also occur in the Gulf region. Temperature and illumination are discussed in terms of maximal seasonal growth, while salinity is considered in terms of tidal and brackish areas of estuaries. Nitrate, phosphate, pH, dissolved oxygen, and physical factors are considered in the distribution of species and their growth rates. The effects of sedimentation, tidal currents, storm winds, ice, and freezing are described.

103 Cook, T. D., ed., 1971, Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoirs 18, Symposium Proc., Houston, Texas, December 6-9, 412 p.
Collection of papers covering the many problems and newest technology concerning underground waste disposal. Individual papers relative to this bibliography are cited under separate authors.

104 Cooke, W. L., 1975, Planning the thermal town (abs): Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract Volume, VIII-4.
Proposals are outlined for the layout and construction of towns near geothermal resources where after some of the energy was converted into electricity the surplus heat would be used to produce clean steam and high temperature water for use in industries and provide the citizens with a heat service which would not be dependant upon the destruction of combustible materials or the misuse of electricity. Proposals are also made for the development of resources not suitable for producing electricity as a source of heat energy.

105 Copeland, B. J., 1964, Industrial pollution in marine ecosystems: Comm. Int. Explor. Sci. Mer. Medit., Symp. Pollut. mar par Microorgan, Prod. Petrol. Monaco., p. 79-88.
With little daily tide and limited exchange of water with the open Gulf, waste waters mix with the receiving bay waters to provide new regimes that lead to ecosystems hitherto unknown to science. Some of the resultant characteristics of the strange new ecosystems are discussed in this

paper. Abnormally high concentrations of phosphate-phosphorus, Ohle anomalies, abnormal redox potentials, reduced species diversity, toxicity, and community metabolism anomalies are important characteristics and should be carefully examined in assessing pollution effects. Also includes a discussion of the importance of freshwater inflows as a major purifying influence. The use of water upstream by the ever increasing numbers of reservoir dam systems is directly contributing to the increasing severity of waste disposal in downstream rivers and bays.

106 Copeland, B. J., 1965, Evidence for regulation of community metabolism in a marine ecosystem: Ecology, v. 46, no. 4, p. 563-564.
The light intensity on a marine ecosystem containing Turtle Grass as the dominant producer was changed from 1500 ft-c to 230 ft-c. Immediately after the light reduction, community metabolism decreased rapidly. This was followed by a gradual increase in metabolism until it reached the previous level. The dominant producer changed from Turtle Grass to blue-green algae.

107 Copeland, B. J., 1966, Effects of industrial waste on the marine environment: Jour. Water Pollut. Cont. Fed., v. 38, no. 6, p. 1000-1010.
Water quality characteristics of St. Joseph's Bay, Florida, a bay heavily polluted by industrial effluents, were used to show the effects of industrial pollution on a marine estuary. The effects demonstrated were as follows: 1) Reducing-type environments were indicated by both redox potentials and Ohle anomalies near the industrial effluent outfall, with decreasing effects as distance from the outfall increased. 2) Species diversity was less near the entrance of the effluent and greater as distance increased. 3) Concentration of phosphorus near the effluent entry point was more than 10 times that in normal bay water; 4) Measurements of metabolic rates of fishes in various industrial wastes indicated rates greater than normal, even though the effluent was not toxic to the fish. 5) Studies of community metabolism indicate that holding the effluent a number of days for biochemical action improved the quality of the aquatic community receiving the effluent.

108 Copeland, B. J., 1966, Effects of decreased river flow on estuarine ecology: Jour. Water Pollut. Contr. Fed., v. 38, no. 11, p. 1831-1839.
Many important commercial and sport fishes and invertebrates use estuaries during some stage of their development. Estuaries are probably the greatest producing areas accessible to man for available protein. They are also extremely important for recreational and industrial uses. The practice of decreasing river flow by the installation of reservoirs is frequently followed without consideration or prior knowledge of the effects downstream, particularly in the estuaries.

109 Copeland, B. J., 1967, Environmental characteristics of hypersaline lagoons: Contr. Mar. Sci. Univ. Texas, v. 12, p. 207-218.
Chemical characteristics of naturally occurring hypersaline lagoons are discussed. The possible impacts of desalinization plant effluent on the existing estuarine environments are integrated into the characteristics of natural hypersaline environments. Data concerning the salinity and species diversity of a Mexican lagoon are given for a five-year period. Differential ion precipitation, alkalinity, pH, and oxygen saturation versus salinity are discussed for evaporated seawater. The diurnal characteristics of dissolved oxygen, carbon dioxide, and temperature in natural hypersaline waters are included.

110 Copeland, B. J., 1970, Estuarine classification and response to disturbances: Trans. Amer. Fish. Soc., v. 99, no. 4, p. 826-835.
The estuarine systems of the United States have been classified into types based on broad similarities and include five main categories: 1) naturally stressed systems of wide latitudinal range; 2) natural tropical systems of high diversity; 3) natural temperate systems with strong seasonal programming; 4) natural arctic systems with ice stress; and 5) emerging new systems associated with man. The response to disturbances is related to the system type. Those already subjected to energy-requiring stresses are more likely to resist changes than those adapted to relatively constant environments. Due to the absence of long periods for adaptation and evolution, the new emerging systems tend to be erratic and unstable.

111 Copeland, B. J., 1974, Impoundment systems: in Odum, H. T., Copeland, B. J., and McMahan, E. A., eds., Coastal Ecological Systems of the United States, Vol. 3, The Conservation Foundation, Washington, D.C., p. 168-179.
This publication is concerned with the class of disturbed systems that result when part of an estuary is isolated from circulation by spoil, banks, dredgings, or dams. These estuaries are vulnerable areas which are important for nursery grounds of many commercial and sports fishing organisms; the removal of them by impoundment considerably lowers the productivity of the coastal systems. These marsh and mudflat systems are also important for nutrient regeneration and cycling of organic matter, thus making them important to primary productivity as well. The incoming energies of organic fuels from rivers, marshes and mudflats and the energies of circulation necessary for system maintenance are limited through the practice of impoundment.

112 Copeland, B. J. and Bechtel, T. J., 1974, Some environmental limits of six Gulf Coast estuarine organisms: Contr. Mar. Sci. Univ. Texas, v. 18, p. 169-204.

Gross temperature, salinity, location and seasonal ranges and optima were established for Menhaden, Sand Trout, Blue Crabs, White Shrimp, and Brown Shrimp. A computer sorting technique was used for relating catch data to environmental characteristics. Environmental variable interactions were considered as related to habitat, migration and estuarine utilization. Each species and its relationship to the environment and environmental variables is discussed in some detail.

113 Copeland, B. J. and Dickens, F., 1974, Systems resulting from dredging spoil: in Odum, H. T., Copeland, B. J., and McMahan, E. A., eds. , Coastal Ecological Systems of the United States, vol. 3, The Conservation Foundation, Washington, D. C., p. 151-167.

Interruption of normal pathways of energy flow can result from dredging operations. The placement of deep channels causes channeling of tidal currents, thus changing normal circulation patterns and usual transport mechanisms for incoming foods and flows. The construction of "spoil banks," usually resulting from disposal of dredging spoil, not only modifies the current mechanisms by physical barriers, but covers large areas with a thick layer of sediment that eliminates the normal bottom component of biological energy cycling.

Characteristic ecological systems result from the dredging modification, governed by the new flow patterns and/or by the abrupt change results of dredging operations, enough ecological information exists from scattered studies to construct a picture of a characteristic dredging-affected system.

114 Copeland, B. J. and Dorris, T. R., 1964, Community metabolism in ecosystems receiving oil refinery effluents: Limnol. and Oceanol., v. 9, no. 3, p. 431-447.

Community metabolism in oil refinery holding ponds was higher than in most natural communities and lower than in sewage oxidation ponds. Diffusion of oxygen from the atmosphere was a major contributor of oxygen to the system during winter and in the first few ponds of the series. Efficiency of the algae in converting solar energy to chemical energy was greatest during fall and spring, when sunlight was more nearly optimal, and lowest in winter, when sunlight was below optimal. Algae in oil refinery effluent are less efficient than algae in sewage communities or natural climax communities. The direct effect of temperature on the bioactivity of the oil refinery effluent community was small. The community was moving toward a production/respiration ratio of about unity at the end of holding time.

115 Copeland, B. J. and Hoese, H. D., 1966, Growth and mortality of the American Oyster, *Crassostrea virginica*, in high salinity shallow bays in central Texas: Pub. Mar. Sci. Univ. Texas, v. 11, p. 149-158.

Oyster growth and mortality on the Texas Coast are discussed with particular reference to the area around Port Aransas. The authors attempt to correlate growth rates with temperature and salinity. Includes discussion of mortality due to extremes in temperature and salinity and a description of the optimal conditions for the area.

116 Copeland, B. J. and Jones, R. S., 1965, Community metabolism in some hypersaline waters: Texas Jour. Sci., v. 17, no. 2, p. 188-205.

Some physical characteristics of the hypersaline Laguna Madre of Mexico, salt evaporating ponds of Puerto Rico, and tidal pools of the Texas coast are discussed. The salinity of these environments ranged from 75 to 225 parts per thousand. Animal and plant populations were very restricted. Community metabolism was lower than most shallow marine bays and the ratio of photosynthesis to total respiration of the community was less than one. The metabolic characteristics of the hypersaline community resemble those of polluted environments.

117 Cooper, A. W., 1974, Salt Marshes: in Odum, H. T., Copeland, B. J., and McMahan, E. A., eds., Coastal Ecological Systems of the United States, Vol. 2, The Conservation Foundation, Washington, D. C., p. 55-98.

As a consequence of the rigorous environment of the salt marsh, only a relatively small number of plants and animals are able to tolerate the conditions found there. Thus, there is a rather high degree of similarity in the kinds of species present in different United States salt marshes. Grasses of the Genus Spartina and species of Juncus and Salicornia are almost universal in their occurrence, as are certain kinds of animals such as fiddler crabs and mussels. Discussion is centered on the fact that despite this overall taxonomic similarity, certain species distributions combine with physiological factors to produce several rather clearly defined marsh types in United States estuaries.

118 Coulbois, P. and Herault, J. P., 1975, Conditions for the competitive use of geothermal energy in home heating (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VIII-5.

The use of low temperature (55-80°C) geothermal energy requires for each operation a large investment (of the order of at least 5 to 6 million French francs, 1974) which is nondivisable and in part, independent of the quantity of heat to be furnished.

Nonetheless, it is possible to vary the thermal power of the installation by making use of hot water pumping, which involves the operating costs.

Competiveness of the geothermal installation can be achieved only in terms of maximum pressure and annual heat output, which are variable according to the resource (localization, temperature) and the characteristics of the secondary function. As a function of these various parameters, the cost of geothermal heat can accordingly be calculated and thus compared to the cost of competitive methods.

119 Courtenay, W. R., Jr., Herrema, D. J., Thompson, M. J., Azzinaro, W. P., and van Montfrans, J., 1974, Ecological monitoring of beach erosion control projects, Broward County, Florida, and adjacent areas: U. S. Army Coastal Eng. Research Center, Tech, Memo, no. TM-41, 88 p.

The purpose of this study was to monitor the biological effects of dredging for a beach fill and nourishment project off the beaches of northern Broward County. Comparative investigations were made in other localities in south Florida. Dredge-and-fill operations are proposed for each of these areas for erosion control. Ecological data on conditions are recorded from these sites.

120 Cowardin, L. M. and Myers, V. I., 1974, Remote sensing for identification and classification of wetland vegetation: Journ. Wildlife Management, v. 38, no. 2, p. 308-315.

This is a technical report on the acquisition of multispectral photography and ground truth on an area in Minnesota, to identify and map wetlands less than two acres in size, to map emergent vegetation in lakes, and to explore the feasibility of classifying vegetation from aerial photographs. Several vegetation types and species groups were recognizable with the aid of color, color infrared, and black and white infrared photography. Proper timing of flights, use of multispectral photography, and knowledge of the ecology of the area are considered essential for wetland mapping by remote sensing.

121 Cummins, K. W., 1976, Use of macroinvertebrate benthos in evaluating environmental damage: W. K. Kellogg Biological Station, Michigan State University, Hickory Corners, Mich., 11 p. (NTIS:CONF-750646-2).

The categorization of running-water macroinvertebrates into functional groups based on their nutritional source and behavioral and morphologic adaptations of food gathering is discussed. The importance of functional groups as processors of organic matter, detritus, and instream primary production is the basis of their usefulness as indicators of environmental damage. Changes in the relative dominance of macroinvertebrate functional groups reflect alterations in the balance between the inputs of particulate organic matter of terrestrial origin, including the particle size distribution of such detritus, and aquatic primary production.

122 Cutshall, N. H., 1974, Metal in estuaries: School of Oceanography, Oregon State University, Corvallis, Oregon, 7 p. (NTIS:RLO-2227-T12-50).

A review of data on metal pollution in estuarine systems showed that metals appear to undergo reactions in estuaries. Whether these reactions are toward increaed or lessened solubility may depend upon the specific metal and estuary. Seasonal variations are possible. Changes in physical form can be expected to affect the transport routes and rates of metals in the coastal zone and their persistence in estuaries. Changes in both physical and chemical form influence the biological significance of metals because toxicity and assimilation efficiency both depend heavily upon chemical form.

123 Cypert, E., Komarek, E. V., Sr., Wolfe, C. W., Chamrad, A. D., Dodd, J. D., Soutiere, E. C., Bolen, E. G., Kirsch, L. M., Kruse, A. D., Klebenow, D. A., and Westemeir, R. L., 1972, Tall timbers fire ecology conference: Tallahassee, Florida: Tall Timbers Research Sta., 12th annual proceedings, 1972, Lubbock, Texas, June 8-9, 1972. Bull. 12, 492 p.

Following is the continuation of the list of titles and authors of the papers presented: Plant Succession on Burned Areas in Okefenokee Swamp Following the Fires of 1954 and 1955, by Eugene Cypert. Ancient Fires, by E. V. Komarek, Sr. Effects of Fire on a Sand Hills Grassland Environment, by Carl W. Wolfe. Prescribed Burning and Grazing for Prairie Chicken Habitat Manipulation in the Texas Coastal Prairie, Albert D. Chamrad and J. D. Dodd. Role of Fire in Mourning Dove Nesting Ecology, by Edward C. Soutiere and Eric G. Bolen. Prairie Fires and Wildlife, by Leo M. Kirsch and Arnold D. Kruse. Habitat Requirements of Sage Grouse and the Role of Fire in Management, by Donald A. Klebenow. Prescribed Burning in Grassland Management for Prairie Chickens in Illinois by Ronald L. Westemeier.

124 Dan, F. J., Hersam, D. E., Kho, S. K., and Krumland, L. R., 1975, Development of a typical generating unit at The Geyers geothermal project--a case study (abs):in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May, 1975, Abstract volume, VII-10.

Since 1958 Pacific Gas and Electric Company and its steam suppliers have been developing the only commercial geothermal development for the production of electric power in the United States. Located at The Geyers in Northern California, this project is the largest geothermal installation in the world. Environmental, geographical and resource utilization problems continue to challenge this project, such that the period for design , regulatory approvals, and construction of a typical new unit is now in excess of five years. At present, 502,000 kw(net) of generating capacity have been placed in service and over 400,000 kw new capacity is planned.

Because the cost of electric power produced by geothermal energy compares favorably to that produced from other sources and because it is a secure, domestic energy source, it had been planned to install new capacity at The Geysers at a rate of about 100,000 kw a year. However, changing environmental requirements and an air emission problem requiring new technology have delayed this schedule. This paper describes the development of a typical new geothermal unit from project inception and planning, through engineering, construction and startup and complements other papers in the symposium describing different facets of this project. It is believed very likely the steps described could be typical of geothermal development in the USA and might benefit others soon to participate in the development of geothermal energy.

125 Darnell, R. M., 1961, Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana: Ecology, v. 42, no. 3, p. 553-568.

The Lake Pontchartrain community is a broadly open system exchanging nutrients, producers, and consumers with adjacent freshwater and saltwater areas as well as with neighboring marshes and swamps. Consumers within the lake apparently depend in great measure upon primary production which takes place outside the lake, and the estaurine community may be trophically unbalanced. The most conspicuous single food item in the diets of the consumers of this community is organic detritus with its attendant bacteria. Individual species do not appear to conform to specific trophic levels. An alternative model of the trophic relations of the community is presented which represents the observed food of each species in the form of a spectrum and in which each food type can be represented quantitatively and comparatively. The really abundant consumer species of the Lake Pontchartrain community comprise two groups: those which feed heavily upon organic detritus and those which exhibit a broad range of food tolerance.

126 Darnell, R. M., 1968, Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community: Pub. Inst. Mar. Sci. Univ. Texas, v. 5, p. 353-416.

The physical environment of Lake Pontchartrain was found to be characterized by moderate temperature, generally low salinity, and very high turbidity, although considerable variations in these factors were noted. Food studies, including 1,399 quantitative and about 100 qualitative stomach analyses, were carried out on thirty-five of the most important species comprising the estuarine community. A definite ontogenetic progression of food stages was recognizable in many species, and most were considered to be omnivorous. Organic detritus was prominent in the diet of most species. Two partial food chains (planktonic and benthonic) were found to support the top predators, but distinct "trophic levels" among the consumers were not recognizable.

127 Darnell, R. M., 1976, Impacts of construction activities in wetlands of the United States: Report to the Environmental Protection Agency by Tereco Corporation, College Station, Texas. Ecological Research Series, no.EPA-600/3-76-045, 392 p.

This report contains discussion of water, soil, and aquatic environments, within natural aquatic systems as well as a review of the biology of these systems. Physical and chemical effects as well as biological effects of construction activities which affect wetlands are considered. A section on synthesis discusses wetland deterioration, immediate and long-range steps for reduction of deterioration, and common sense versus modeling approaches to the quality control problem. Contains an extensive bibliography of over 1000 references.

128 Davis, J. C., 1975, Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. Jour. Fish. Res. Bd. Can., v. 32, no. 12, p. 2295-2332.

This article reviews the sensitivity, responses, response thresholds, and minimum oxygen requirements of marine and freshwater organisms with strong emphasis on Canadian species. The analysis attempts to define low dissolved oxygen thresholds which produce some physiological, behavioral, or other response in different species. Oxygen availability is discussed with reference to seasonal, geographical, or spacial variation in dissolved oxygen. Incipient oxygen response thresholds are used in a statistical analysis to develop oxygen criteria for safeguarding various groups of freshwater and marine fish. Oxygen tolerances and responses of aquatic invertebrates to low oxygen are reviewed for freshwater and marine species according to habitat. It is suggested that criteria for protection of aquatic life be implemented by groups of experienced individuals. Each water body and its aquatic life should be considered as a unique situation and criterial application should not encompass diverse areas, habitats, or biological associations as if they were identical.

129 Dean, J. M., 1976, Response of estuarine fish embryos to environmental temperature shock: Annual Progress Report, January 14, 1975-January 13, 1976, South Carolina University, Columbia, S. C., p. 29 (NTIS:SRO-869-1)

Indicates that the most sensitive stages to acute thermal shock were the 1-2 and 2-4 cell stages of periods of cell division. Late embryos and larvae were more tolerant of temperature and chemical stress than were juveniles or adults. Increased incubation temperatures shortened the time to hatching and fish reared at high but non-lethal temperatures had higher feeding rates than those reared below an apparently sensitive environmental level defined in the report. The results of the exposure of different developmental stages to chlorine and temperature at different durations are still undergoing analysis.

130 de Cachard, M., 1975, Greenhouse heating using "tepid" water (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VIII-6.

Describes an experiment carried out at the Centre d'Etudes Nucleaires of Grenoble for studying the possibility of using tepid water, from 20 to 35°C, for greenhouse heating, by means of plastic jackets resting on the soil, through which water circulates with a low velocity under low pressure. Excellent results were obtained; in particular, it was possible to maintain a temperature of 9°C in the greenhouse under an external temperature of -11°C, using water having a temperature of only 33°C. Use of this method in combination with a geothermal heat source is investigated;several economic facts are provided and an attempt at optimalization is presented.

131 Delaune, K. M., 1972, Proceedings of the recreational boating seminar held in Galveston, Texas, on December 17, 1971: Texas Engineering Experiment Station, College Station. Industrial Economics Research Division. TAMU-SG-72-103. NTIS: COM-72-10374, 84 p.

The leisure industry is the third largest in the nation. Of all water-related activities, recreational boating is one of the fastest moving. At the seminar in Galveston, marine insurance, marketing trends, maintenance, repairs and boating safety were discussed.

132 Dell, J., 1966, Study of the physical and chemical properties of water and soils of marshes as these properties relate to the success of waterfowl food and cover plants, Part I. Department of Agronomy, Cornell University, Ithaca, N. Y., (NTIS:AD-643 352), 47 p.

Total alkalinity, pH oxygen and temperature measurements were taken at 6-inch intervals of water depth in each of several 1/10 acre marshes every week during the growing season. The oxygen content ranged from 3.1 to 14.8 ppm during the period from 8 a.m. to 5 p.m. This change in oxygen level is a reflection of the biological activity of the marshes. Total alkalinity determinations showed a significant decrease for all marshes. In 1965, 94% of all determinations feel in the range of 0.50 ppm. The average alkalinity for the four marshes of any one depth was approximately 30 ppm. The data from soil tests, taken every 3 months from the bottom soils of each of the marshes showed a trend toward higher levels of iron. The water from the main water supply and the center feeding canal was sampled at weekly intervals throughout the season. These samples were analyzed by spectrographic methods for 15 nutrients. No significant changes from 1964 values were seen.

133 Dial, D. C., 1970, Pumpage of water in Louisiana in 1970: Louisiana Dept. Conserv., Geol. Survey and Dept. Public Works, Water

Resources Pamph. no. 26, July.
The report summarizes surface and ground-water pumpage in Louisiana for 1970 by parish and water use categories. Each of the water use categories, namely public supply, industrial, thermoelectric, rural, and irrigation are described in the text.

134 Dickey, P. A., Collins, G., and Fajardom, I., 1972, Chemical composition of deep formation waters in southwestern Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 56, p. 1530-1570.
Forty-one formation-water samples from gas fields near Lafayette in southwestern Louisiana were analyzed by the U. S. Bureau of Mines to determine whether there is any difference in chemical composition between waters in normally pressured and abnormally pressured geologic intervals. The analytical data plus associated geologic data indicate that the concentration of dissolved solids in the waters is related to the degree of compaction of the adjacent shale, and that most of the samples taken from high-pressure zones are less concentrated in dissolved solids than those taken from normally pressured zones.

135 Dickinson, G., 1953, Geological aspects of abnormal reservoir pressures in Gulf coast Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 410-432.
High pressure zones commonly make drilling of wells most difficult in a belt about 50 miles wide along the coastal plain northwest of the Gulf of Mexico from the Rio Grande to the Mississippi Delta. This study is an attempt to link geological factors with occurrences of abnormal pressure in order to provide a better understanding of their origin. The area considered in this report is the Louisiana Gulf Coast Region.

Abnormal pressure has been defined as any pressure which exceeds the hydrostatic pressure of a column of water containing 80,000 parts per million total solids.

Dangerously abnormal pressures occur commonly in isolated porous reservoir beds in thick shale sections below the main sand series. Their locations are controlled by regional facies changes in the Gulf Coast Tertiary province, and they appear to be independent of depth and geological age of the formation.

The high pressures are caused by compaction of the shales under the weight of the overburden, which is equivalent to approximately one pound per square inch per foot depth. The difference in density between gas and water causes abnormal pressure where hydrocarbon accumulations occur above water, irrespective of whether the water is at normal or abnormal pressures. The magnitude of this pressure depends on the structural elevation above the source of pressure in the water, and may cause very high pressure gradients in isolated sand bodies. However, the trend of pressures in the Gulf Coast region indicates that maximum pressures probably do not exceed 90 per cent of the overburden pressure.

The abrupt increase in pressure above normal hydrostatic pressure commonly occurs over a very short vertical interval which makes control difficult. Successful drilling through abnormal pressure zones necessitates cementing casing below the main sand series and above the high pressure zones so that heavy mud may be used without loss of circulation.

Useful figures include reservoir pressure versus depth for Louisiana Gulf Coast wells and a sketch map showing the location of these wells, and a stratigraphic correlation chart of abnormal pressure occurrences.

136 Dickson, K. L., Hendricks, A. C., Crossman, J. S., and Cairns, J., 1974, Effects of intermittently chlorinated cooling tower blowdown on fish and invertebrates: Env. Sci. and Tech. v. 8, no. 9, p. 845-850.

An in situ bioassay was conducted to evaluate the effects of intermittently chlorinated cooling tower blowdown from a power plant of Bluegill Sunfish and snails. No fish deaths that could be attributable to blowdown discharges occurred. However, the blowdown was acutely toxic in 72 hours to 50% of the snails exposed to less than 0.04 ppm total residual chlorine for less than 2 hours/day, to 80 mg/l copper plus other blowdown constituents. The impact of cooling tower blowdown on the total ecology of a nearby river was probably insignificant.

137 Diener, R. A., 1973, Observations on the hydrology and marine organisms of the tidal Colorado River and adjacent waters, Texas, February-June 1962: Contr. Mar. Sci. Univ. Texas, v. 17, p. 99-110.

Sampling stations included the Colorado River, Matagorda Bay, East Matagorda Bay and the Intracoastal Waterway. Surface salinities ranged from 1.0 to 31.2 ppt and bottom salinities from 10.6 to 31.2 ppt. Surface salinities fluctuated most in the Colorado River, increasing with flood tide and decreasing with the ebb. Least salinity fluctuation occurred in East Matagorda Bay which has a reduced tidal influence and a high evaporation-precipitation ratio. Surface and bottom salinity differences were greatest in the river and the Intracoastal, and least in the bays where mixing was great. Water temperatures generally followed those of the air. Temperatures of bottom waters were warmer than those of the surface during February and early March. Vertebrates and invertebrates were collected during the study, although no correlations with the hydrology were attempted.

138 Dodd, F. J., Johnson, A. E., Ham, W. C., 1975, Material and corrosion testing at the Geysers geothermal steam power plants (abs): in Second United Nations Symposium on the Development of Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-11.

Pacific Gas & Electric Company's ten operating units utilize geothermal steam to directly propel steam turbines and recirculate condensed steam as cooling water. Corrosion is a major consideration in the selection of materials exposed to the atmosphere, soil, geothermal steam, or condensate at the Geysers. Initial tests lead to the selection of conventional turbine, stator, rotor and blading materials, aluminum and austenitic stainless steels for the condensate system and aluminum for line hardware. Atmospheric corrosion testing has been performed and has shown that austenitic stainless steels and aluminum alloys have satisfactory corrosion rates. Galvanizing, cadmium plating, copper alloys and carbon steel exhibited excessive corrosion.

Steam turbine blades have suffered repeated blading fatigue failures. Mechanical properties of the 12% chromium stainless steel blading materials are sensitive to slight variations in heat treatment and are notch sensitive in Geysers steam. Fatigue tests of blading material have been initiated to determine a satisfactory heat treatment or a more suitable material for turbine blading. Chemical treatment of recirculating condensate to remove hydrogen sulfide gas has been initiated. Tests were made in the condensate system in order to determine the effects on material corrosion rates. Tests to date reveal increased corrosion rates with chemical addition.

139 Donaldson, E. C., 1971, Injection wells and operations today, in Cook, T. D., ed., Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoir 18, Symposium Proc., Houston, Texas, December 6-9, p. 24-46.

Bureau of Mines engineers have investigated the feasibility and limitations of the underground injection of industrial wastes by observing installations at industrial plants, cities, and oil fields. The chemical industry is using about 175 deep wells to inject approximately 30 million gal per day of waste solutions. The wastes are 1) inorganic salts, 2) mineral and organic acids, 3) basic solutions, 4) chlorinated and oxygenated hydrocarbons, and 5) municipal sewage.

The wells, ranging from 1,000 to 8,000 ft (300-2, 440 m) in depth, are completed in three general types of formations: (1) unconsolidated sand, (2) consolidated sandstone, and (3) vuggy carbonate rock. The chemical and physical characteristics of the formation and waste dictate the design of the injection system and govern its operation.

Commonly, underground injection is the most economical method for disposal of liquid wastes that are not amenable to surface treatment. Operating costs are lower for pretreatment and subsurface disposal than for surface treatment systems, and plant area requirements are less. Chemical treatment is minimal, and generally the only physical treatment required for underground injection is filtration. A discussion of disposal of oil field brines is included.

140 Dorfman, M. H., 1975, Subgroup 3: Geopressured systems, in Magnitude and deployment schedule of energy resources: Portland, Oregon

State Univ. Pub., Conf. Proc., Corvallis, Oregon, 21-23 July 1975, p. 70-76.
Geothermal zones and power production estimates are discussed; a map shows resource areas.

141 Dorfman, M. H., 1975, Water required to develop geothermal energy. Problems of residuals disposal and geopressured zones as water sources, *in* Gloyna, E. F., Woodson, H. H., and Drew, H. R., eds., Water management by the electric power industry: Univ. Texas, Austin, Water Resources Symposium no. 8, p. 230-241.
Geologic modes of geothermal occurrence that are in current use and those that appear to represent potential sources of useful energy are described. The concomitant water problems and benefits that may be associated with each type are discussed. Vapor dominated, liquid-dominated, and geopressurized zones are considered.

142 Dorfman, M. H., and Deller, R. W., eds., 1975, Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, 362 p.
A collection of papers covering many facets of research related to the development of geopressured geothermal energy along the Texas-Louisiana Gulf Coast. A transcript of the open discussion that followed the presentation of individual papers is also given, as well as the presentation of the panel discussion summarizing the technology development and future projects for geopressured geothermal resources. Individual papers are cited in this bibliography under separate authors.

143 Dorfman, M. H., and Deller, R. W., 1976, Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 1, Summary and future projections: Univ. Texas, Austin, Center for Energy Studies, February 23-25, 82 p.
Results of an ERDA-sponsored management and scope-of-work study to determine the feasibility of electric power generation through development of geopressured geothermal aquifers underlying the U. S. Gulf Coast are summarized. The study concerned geological background, resource assessment, well design, reservoir research and technology, methods of resource utilization, and legal, institutional, and environmental factors in resource development. Drilling and completion technology are adequate for successful development of geopressured geothermal wells. Electricity generation is economically and energetically attractive if fluid temperatures, production rates, and methane content approach those assumed in the study: 325°F well head, 40,000 BPD, and 40 cu ft/BBL. Recommendations, a time schedule, and cost estimates for further research and technology development are included.

144 Dorgelo, J., 1976, Salt tolerance in crustacea and the influence of temperature on it: Biol. Rev., v. 51, p. 255-290.

An extremely good discussion of the various aspects of salinity tolerance in crustacea. Includes a classification system and discussion on the problems associated with placing organisms within such a scheme. Also classifies salinity with regard to temperature interactions and the effect on crustaceas. The author also indicates that variation arises from sex, time and duration of spawning, and age. By comparison with the progress in the understanding of fish migration, emphasis is laid on the necessity to investigate endocrinological aspects (which are strongly neglected in crustacea) as salinity and temperature very probably are of secondary importance.

145 Dregne, H.D., ed., 1977, Managing saline water for irrigation: International Salinity Conference, Texas Tech Univ., Lubbock, Texas, 16-20 August 1976, 618 p.

Irrigation water salinity is becoming an increasingly serious problem as water of less and less desirable quality is exploited for irrigation and as greater intensity of water use leads to degradation. Deteriorating quality, combined with rapidly increasing energy costs, has caused a crisis in water use in pump-irrigated areas. Similarly, river water have become more highly regulated, water evaporating from reservoirs concentrates the salts, and new irrigation projects aggravate the salinity problem for downstream users.

This volume encompasses the proceedings of a conference to assess the current state of knowledge about managing saline water for irrigation and to present new information on how to cope with salinity. Plant scientists, soil scientists, and engineers representing 20 countries participated in the sessions. Their findings are presented in this volume. The tone of the papers is one of optimism that moderately saline water can be used successfully for irrigation if what is known already and what is being learned now is used effectively. Mixed with the optimism isthe realization that careless management of saline irrigation water can be disasterous to the land and, more importantly, to the people living on that land.

146 Duncun, W.H., 1974, Vascular halophytes of the Atlantic and Gulf Coasts of North America north of Mexico: in Reimold and Queen, eds., Ecology of Halophytes, Academic Press, N.Y. p. 23-50.

Difficulties in delimiting halophytes and halophytic habitats are discussed and an annotated list of halophytes presented. Data included for each species are: the halophytic habitats in which they are reported to occur, the authors reporting the habitats, page citations for these reports, and composites of the coastal geographic distributions compiled from numerous authors. Geographical distributions are analyzed by areas and summarized. The most species, 197, occur in the area from Georgia to Delaware. Thirty-eight occur in Florida, 17 only in Canada, and 32 in every one of the coastal states from Texas into Canada The author indicates that habitat terminology lacks uniformity.

147 Dunham, F., 1972, A study of commercially important estuarine-dependent industrial fishes: Louisiana Wildlife and Fisheries Commission, Division of Oysters, Water Bottoms and Seafoods, Technical Bulletin no. 4, 68 p.
A study of commercially important estuarine-dependent industrial fishes was conducted from July 1969 to June 1972 in the area of the Barataria and Caminada Bays of Louisiana. The purpose of the project was to aid the fishing industry in the best utilization of our fish resources. Data were obtained from both field samples and samples taken at industrial fish companies. The most abundant species in trawl samples was the Bay Anchovy and the most abundant commercial fish species was Atlantic Croaker. The monitoring of fish eggs and larvae entering the bay revealed their seasonal influxes.

148 Durhan, C. O., and Peoples, E. M., 1956, Pleistocene fault zone in southeastern Louisiana (abs): Gulf Coast Assoc. Geol. Socs. Trans., v. 6, p. 65-66.
The Baton Rouge fault zone in the Florida Parishes of Southeastern Louisiana consists of several east-west faults which were subject to movement in the Late Pleistocene. These faults may be mapped on the surface in a belt over seventy miles long and up to 8 miles wide which extends generally westward from the vicinity of Slidell, St. Tammany Parish, to Baton Rouge. Subsequent displacement along the faults has produced escarpments ranging up to twenty feet in height. Recorded vertical displacement in the subsurface varies from 200 to 450 feet (outside the study zone).

149 Dvorov, I. M. and Ledentsova, N. A., 1975, Utilization of geothermal water for domestic heating and hot water supply (abs): Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VIII-7.
A number of schemes of utilization of geothermal water have been developed. There are schemes for direct and parallel utilization of geothermal water, a scheme with peak heating and compression thermo-transformer, a scheme with combined systems of water

and air heating. The choice of the best schemes of utilization of geothermal energy is carried out according to different factors: the depth of bed, strength of rocks, yield of wells, temperature, rate of mineralization, chemical composition, climate, cost of fuel, distance to the sites of use.

The possibilities of application of different types of systems of heating were investigated: they are panel (ceiling-floor-type), convector, air heating systems, new types of heating installations. The installations based on utilization of geothermal water are already exploited in some regions.

150 Eaton, B. A., 1972, Effect of overburden stress on geopressure prediction from well logs: Jour. Petroleum Technology, v. 24, August, p. 929-934.

A theory is presented concerning the effect of overburden stress gradient on geopressure magnitude prediction. The theory involves the relationship of overburden stress, rock matrix stress, pore pressure, normal shale compaction, and the technique used to predict geopressure magnitudes from resistivity and sonic log data.

151 Edwards, P., 1969, Field and cultural studies on the seasonal periodicity of growth and reproduction of selected Texas benthic marine algae: Contr. Mar. Sci. Univ. Texas, v. 14, p. 59-114.

Seasonal distributions of species were determined over a 24-month period. Correlations were made between changes in algal vegetation and variations in environmental factors. Temperature appears to be of primary importance in the seasonal distribution of the algae. Seasonal variation in day length acting alone or in conjunction with temperature variations, appear responsible for alternations of the flora. Seasonal variations in light intensity do not appear to be a factor.

The study area was in Aransas and Redfish Bays and off of the Port Aransas jetties. Each species is discussed in relation to laboratory and field observations as to the upper and lower temperature limits and the various stages of the life cycle as related to temperature.

152 Edwards, P. and Kapraun, D. F., 1973, Benthic marine algal ecology in the Port Aransas, Texas area: Contr. Mar. Sci. Univ. Texas, v. 17, p. 15-52.

The marine benthic algal flora . in stations in Aransas Bay, Redfish Bay, and the nearshore Gulf of Mexico were considered in terms of spatial and seasonal distribution of the species. Correlations were made between observed distribution of each species in the area and various environmental factors (temperature, light intensity, daylenght, salinity, tides, wind, and tudbidity) in an attempt to determine causes of the various distributions.

Regular seasonal changes in distribution were brought about mainly by the pronounced temperature range of 17°C and salinity variations. Also considered was the effect of freshwater input from Hurricane Beulah.

153 Edwards, T., 1974, Impact of State and Federal law on development of geothermal resources in Texas: Austin, Texas Governor's Energy Advisory Council, Natl. Science Found. Proj. L/R-9, Final Rept., Oct. 31, 1974.

The significant geothermal resources in Texas consist of enormous reservoirs of hot, geopressured water which formed along the Gulf Coast when water-laden sediments were deposited between surrounding impermeable strata so that the water which would otherwise have been forced out of the sediments was unable to escape. These deposits exist under tremendous pressure created by the weight of the overburden. A geopressure source absorbs heat indirectly, because the geopressured deposits create an insulating barrier that traps and absorbs thermal energy. The water from a geopressure source will not be as hot as water from a dry steam or wet steam source, but the quantity available is enormous, and the water pressure itself would be an additional energy source along with the thermal energy. The water may be fresh, or nearly so, and it will contain significant amounts of recoverable methane gas in solution. It may be possible to utilize the water pressure, thermal energy, and the methane gas to generate electricity in small power plants at the recovery site, and the water that has been passed through the turbines and heat exchangers may be a valuable by-product in itself, depending on its quality and regional demands of agriculture and industry. One of the impediments to the development of this resource, considering the very sizeable commitments of capital which would be involved, is the uncertain legal status of geothermal resources. This report attempts to locate geothermal resources which can be developed under the law as it now exists.

154 E. G. and G. Inc., 1971, Potential environmental modifications produced by large evaporative cooling towers: E. G. and G. Inc. Environmental Services Operation 1971, EPA Program #16130 DNH 01/71.

Development of techniques for evaluating the effects of plumes from evaporative cooling towers.

155 Eiler, H. O. and Delfino, J. J., 1974, Comparative effects of two modes of cooling-water discharge on Mississippi River biota and environmental ecosystems: Environmental effects of cooling systems at nuclear power plants, Symposium Proceedings, Paper, and Discussion, Oslo, Norway, 26-30 August 1974, International Atomic Energy Agency, Pub. no. IAEA-SM-187/16, p. 685-692.

Environmental studies during operation of two different modes of once-through condenser cooling at the Quad-Cities Nuclear power plant on the Mississippi River are reported. During operation of an interim shoreline discharge, numberous localized changes in biotic communities downstream from the point of discharge compared with pre-operational data were detected. Water temperatures greater than 7°C above ambient and chlorine concentrations of 0.22 ppm were believed to be responsible for adversely affecting downstream biological communities, such as periphyton inhibition and fish displacement. A submerged multi-port diffuser-pipe system provided an alternative method for discharging the heated effluent. Limnological studies during 18 months of station operation, using the diffuser pipe discharge mode, indicated virtually complete mixing of the thermal effluent with ambient river water and subsequent recovery of the previously impacted area.

156 Eiler, H. O., Devik, O., Von Nida, A., Balligand, P., Hatle, Z., Ageev, G., and Delfine, J. J., 1974, Alternative methods for the management of heated effluents, and possible beneficial uses of waste heat. Presented at the International Atomic Energy Agency Conference on Environment Effects of Cooling Systems at nuclear power plants, Oslo, Norway, August 26-30, 685 p.

Methods for management, reduction of negative environmental impacts, and beneficial uses of aquatic thermal discharges are discussed. Topics include two cooling alternatives for the Mississippi River Quad-Cities nuclear plant and their ecological impacts; utilization of power plant waste heat and minerals for aquaculture; the feasibility of a Brayton cycle combined thermal-electrical utility system; use of thermal discharge heat for agriculture, fisheries, and space heating; and exploitation alternatives for waste heat in the U. S. S. R. and Czechoslovakia.

157 Einarsson, S., 1975, Geothermal space heating and cooling (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VIII-8.

Space heating is one of the most successful present applications of geothermal energy. It can substitute the use of more versatile and valuable sources of energy like electricity or fuel oil and eliminate some of the chemical pollution associated with the latter. However, limitations are set by the relatively low temperature level and transportability of geothermal heat as compared to the other energy sources.

The cost structure of geothermal heat delivered to the consumer is analyzed with view on the principal parameters, such as production costs at the source, long distance transportation costs and distribution costs within the marketing area, as well as the temperature.

158 Einarsson, S. S., Vides, R., and Cuellar, G., 1975, Disposal of geothermal waste water by reinjection, in Second United Nations Symposium on the Development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, p. 1349-1363.

Highly mineralized waters represented a major problem for exploitation of the Alhuachapan geothermal field. Large scale reinjection experiments were sucessfully carried out in 1970-71, during which almost 2 million cubic meters of water at 150°C were reinjected at the rates of 91 to 164 liters/sec. by using a combination of gravity and vapour pressure as the driving force. The water was injected into the high-temperature aquifer at depth, and resulting cooling effects were observed. No technical difficulties from scaling were experienced.

It was concluded that reinjection should be carried out within the high-temperature system, which means recycling the water with the residual heat after flashing to the reservoir, thus practically eliminating any danger of insufficient water for heat-extraction, even with limited natural recharge, and possibly effecting significant conservation of energy at the same time.

The local cooling effect around the point of injection, which should be a minimum of 1.5 km away from the production area, was estimated and found to be of minor significance in relation to the expected benefits.

The cost of reinjection was estimated at approximately 1 US mil/kwhr and the reinjection of the waste water is considered a technically and economically feasible disposal method.

159 Elemo, R. O., 1976, Possible use of geopressured aquifers for the short-term storage of energy: Louisiana State Univ., Master's thesis.

Investigation of the technical feasibility of utilizing subsurface geopressured aquifers to store energy during low energy demand intervals of electrical generating companies. Excess electrical energy is utilized to inject water at high pressure into the geopressured aquifer. Energy would then be recovered by production of high pressure water from the aquifer to power a surface conversion unit such as an electricity generating turbine. To describe the process, two computer programs are given, one for a single well in a closed aquifer, and the other for a multi-well system in a closed aquifer.

160 Eleuterius, L. N., 1971, Recent changes in the Louisiana marsh near Vermilion Bay: Gulf Research Reports, v. 3, no. 2, p. 259-263.
The Louisiana marsh in the vicinity of the Mermentau River has in recent years undergone intense dredging operations. The canals crisscross the entire marsh from the saline areas of the south to the freshwater areas to the north. The area has been described as a *Scirpus olneyi* dominated marsh and it has been stated that Vermilion Bay is surrounded by one of the most productive three-cornered grass marshes on the Gulf Coast. This area had originally been studied by others who placed permanent markers in the area in 1951, so that it has been possible to determine changes in the marsh area by comparing present conditions on the same areas as described by previous authors.

161 Elkan, G. H., Willis, C. J., Horvath, E., and Dail, E., 1975, The role of microorganisms in subsurface disposal of industrial wastes in Water: Am. Inst. Chem. Eng. Symposium Series, v. 71, no. 151, p. 313-321.
The role of microorganisms in the subsurface disposal of industrial wastes was investigated. The native microbial populations of three aquifer systems were surveyed. Numbers of heterotrophic bacteria were extremely low, but the organisms isolated proved to be common soil and water bacteria. These may originally have become established as a result of well drilling procedures. A rapid increase in bacterial numbers resulted from waste injection, although the diversity of the microbial population decreased. *Thiobacillus thioparus*, an autotroph, *Desulfovibrio sp*, and methanogenic bacteria, were also isolated. The methanogenic bacteria are presently being identified. The numbers of bacteria declined with increasing well depth and thus the effect of hydrostatic pressure on the growth rate of well isolates was investigated. The microorganisms were shown to decompose the waste but at a low rate.

162 Ellison, S. P., Jr., 1971, Sulfur in Texas: Univ. Texas, Austin, Bur. Econ. Geology Handbook 2, 48 p.
A general overview of sulfur production in Texas. Topics covered include the use of residual hot water in the Frasch process of sulfur mining and sulfur uses and consumption. A map locating salt domes including those actively mined for sulfur on the Gulf Coast of Texas is included.

163 Elmer, D. B., 1976, Legal issues in the development of geopressured geothermal resources of Texas and Louisiana Gulf Coast: Geothermal Energy, v. 4, no. 9, p. 13-19.
This report is divided into two sections, Legal Scholarship and Legal

Support. Scholarship is distinguished from support by concentration on abstract analyses of issues which include resource definition, ownership, taxation, and multistate reservoirs. Support is based entirely on those legal tasks called up by the technical work scheduled in the areas of resource assessment, advanced research and technology, institutional and environmental and resource utilization. The scope of many of the legislative provision in state statutes (including Texas and Louisiana) is limited to leases of state-owned lands and regulation of operation of wells and facilities on all lands. Few of the statues define the resource so as to include all types of geothermal resource, with hot rock massifs and geopressured systems being most often excluded.

164 Energy Research and Development Administration, 1976, An environmental assessment of proposed geothermal well testing in the Tigre Lagoon oil field, Vermilion Parish, Louisiana: Washington, D. C., Energy Research and Devel. Adm., Div. Geothermal Energy, and Baton Rouge, Louisiana, Coast Environment, Inc., 105 p.

This report is an environmental assessment of the proposed testing of two geopressured, geothermal aquifers in central coastal Louisiana. On the basis of analysis of the environmental setting, subsurface characteristics, and the proposed action, potential environmental impacts are determined and evaluated together with potential conflicts with Federal, state and local programs.

Oil and gas wells in coastal Louisiana have penetrated a partially productive geothermal zone of abnormally high-pressured aquifers that also yield large volumes of natural gas. To evaluate the extent to which the geopressured-geothermal water can be used as an alternative energy source and to what extent withdrawal of geopressured water can enhance gas production, it is necessary that flow rates, composition and temperature of fluids and gases, recharge characteristics, pressures, compressibilities, and other hydrodynamic and boundary conditions of the reservoir be determined by means of production tests. Tests are further necessary to evaluate and seek solutions to technological problems.

165 Energy Reserach and Development Administration, 1976, Balanced Program Plan: Analysis for biomedical and environmental research. Volume 9: Geothermal Energy, U.S. Government Printing Office, ERDA-76/116 (v. 9), 56 p.

The goals of ERDA geothermal energy program include the generation of 6000 MW of electric power and the supply of 0.1 quad/year of thermal power for nonelectric applications by 1985. The primary environmental concerns associated with such development are the noncondensible gas emissions, especially hydrogen sulfide; the emissions from cooling towers including salts and dissolved gases; the management of spent geothermal fluids; stimulation of seismic activity by the subsurface injection of spent geothermal fluids; noise;land and resource use alternatives;

and the occurence of accidents such as well blowouts.

A comprehensive program of biomedical and environmental research to investigate and recommend solutions to these concerns is developed. It includes the measurement of source terms, the accumulation of baseline and followup data, the study of local and regional ecosystems, documentation of subsurface effects, cost/risk/benefit analysis of alternate technologies, and an integrated assessment of the health, social, and economic effects of geothermal energy development.

166 Environmental Protection Agency, 1976, Grants for state underground water source protection programs-state underground injection control program, Proposed regulations: Federal Register, pt. II, v. 41, no. 170, August 31, p. 36725-36745.
This document promulgates the proposed additions to be issued by the EPA to 40 CFR Part 35, setting forth regulations governing grants to States to assist in the funding of underground water source protection programs, and the proposed new 40 CFR Part 146, setting forth regulations governing state underground injection control programs (minimum national requirements for effective state programs designed to protect underground drinking water sources from subsurface injection of contaminants.)

167 Environmental Protection Agency, 1976, Health effects of air pollutants: Environmental Protection Agency 335, June, pamph.
Shore description and summary of the six major air pollutants and their effects on human health.

168 Environmental Protection Agency, 1976, Pollution and your health: Environmental Protection Agency Office of Public Affairs (A-107), 17 p.
General discussion of possible threats to human health posed by environmental pollution. Includes air, water, solid wastes, noises, pesticides, and radiation.

169 Environmental Science Technology, 1976, Handling and using dredged material: Environmental Sci. Technology, v. 10, no. 4, p. 326-327.
The author points out that some violence has been done to the aquatic environment by dredging and filling operations. True, dredging of naviagable waters of the U. S. has required a Corps permit under the River and Harbor Act of 1899, but such permits were generally granted when it was thought that no impairment of navigation would ensue. In 1958, the Corps began to examine dredging permit applications with somewhat more environmental scrutiny. The National Environmental Policy Act (NEPA, 1969), 1972 Water Pollution Laws (P. L. 92-500), and 1973 Ocean Dumping Laws (P. L. 92-532) provide that the Corps must carefully weigh environmental, as well as economic and navigational factors in any decision to grant, delay, or deny a dredging permit.

The Corps' power to deny a dredging permit has also been established in the courts. A landmark case (1969), involving a proposed mobile home park in Boca Ciega Bay, Fla., known as the Zabel v. Tabb case, helped establish this power.

170 Eraslan, A. H., 1976, Unified transport approach models for power plant impact in estuaries: University of Tennessee, Knoxville, Tenn., 10 p. (NTIS: CONF-760622-21).

The assessment of environmental impact of power plant operations in an estuary requires the modeling of both physical and biological phenomena. In addition to the direct entrainment and impingement of the aquatic organisms at the intakes, power plants also indirectly affect the biota by altering the ambient hydrodynamic, thermal, and water quality conditions in an estuary. The modeling of both the physical and the biological phenomena can be accomplished by a unified transport approach which employs consistent balance principles, discrete-element formulation, input data, and computational algorithms for the solution of all the required physical and biological variables. One-dimensional models were developed for both tidal-transient and tidal-averaged simulations of the physical conditions and the behavior of the aquatic populations in estuaries.

171 Eraslan, A. H., Barton, J. M., Diament, H., Sharp, R. D., and Bauman, H. F., 1976, Thermal impact assessment of large power plants in coastal regions: University of Tennessee, Knoxville, Tenn., 8 p. (NTIS: CONF-760622022).

The purpose of this study was to investigate the thermal impact in shallow regions near shores resulting from large thermal discharges in deep water. It was concluded that the assessment of the thermal impact of a power plant by a far-field thermal model requires the simulations of both the natural ambient conditions and the operating power plant conditions. Furthermore, it was concluded that the excess temperatures should be based on the simulated local temperature conditions; and they should not be based on the simplifying assumption of a constant ambient temperature value.

172 Espey, W. H., Jr., 1968, Galveston Bay study. Phase I. Technical report: Report by TRACOR to the Texas Water Quality Board, 200 p.

A data collection program in Galveston Bay was delineated and initiated. Thirty-five stations in the bay and ship channel were selected for water sample collection at routine monthly intervals. It was recommended that all data collected in the bay system, both past and present surveys, be gathered and incorporated into an electronic data processing system, and that data management systems be developed to manipulate and perform reduction techniques on this large collection data. Present estuarine data management systems were evaluated, and a system utilizing a library of modules for data processing and display was recommended as most suitable for the requirements of the Galveston Bay study.

173 Espey, W.H., Jr., Hays, A.J., Jr., Bergman, W.D., Buckner, J.P., Huston, R.J., and Ward, G.H., Jr., 1971, Galveston Bay Project Water Quality Modeling and data management. Phase II: Technical Progress Report: Report by TRACOR to the Texas Water Quality Board.

The objective of the Galveston Bay Project was preparation of alternative plans for water quality management of the bay system. Computerized mathmatical models were utilized as management tools to describe the hydraulic behavior and distribution of various water quality parameters in the system. This report discusses progress toward completion of the water quality modeling and data management tasks of the Galveston Bay Project.

174 Estuarine Ecology, 1966, A symposium on the coastal waters of North Carolina, May 12, 1966: Proceedings of the University of North Carolina, 111 p.

The purpose of this symposium was to explore the significance of estuarine ecology research to the development of the coastal region of North Carolina and the research interests and activities of governmental agencies and universities as a basis for an intensified cooperative research effort in estuarine ecology of North Carolina's coastal waters. Includes panel discussions on state agency, Federal agency, and university research interests in estuarine ecology.

175 Fair, H. W., 1974, Social concerns, Nuclear offshore river basin construction: Am. So. Civil Engineers Proc., Jour. Construction Div., v. 100, p. 51-57.
The committee on Social and Environmental Concerns has outlined its purpose "to define and to establish acceptable standards of construction as they affect the environment, esthetics and society". The social and environmental impact of both the offshore nuclear power plant and the multipurpose high dam installation should be analyzed from the viewpoint of the construction process.

176 Fang, C. S., Parker, G. C., Shearis, E. A., and Hargis, W. J., Jr., 1975, Estuarine thermal monitoring program: Astronautics and Aeronautics, v. 35, p. 241-257.
A monitoring program has been designed and operated to measure environmental parameters for a waste heat study of the 1700 megawatt Surry Nuclear Power Plant located on the James River in Virginia. Monitoring techniques include a moving boat system, a stationary tower system, and aerial infrared scanner images of the study area. Data acquired from this program are used in a waste heat study, indicating the state of the environment before and after the power station became operational. The pre-operational data indicate a consistent seasonal pattern or monthly averages of temperature and salinity over two years 1971 and 1972, and 1972 averages being slightly lower as a result of unusual rainfall. Data from the first year of operation (1973) show significant temperature and salinity increases over both comparable pre-operational periods.

177 Faust, C. R., and Mercer, J. W., 1975, Mathematical modeling of geothermal systems (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume IV-14.
Simulation of geothermal systems yields estimates of recoverable energy, helps determine optimum management techniques, and aids in refining descriptions of reservoir geometry, boundary conditions, and rock properties. To develop an appropriate mathematical model, the continuity equations for mass, momentum, and energy in porous media are reduced to two non-linear, partial differential equations in which the dependent variables are fluid pressure and enthalpy. These equations include the effects of phase changes and are applicable to both are solved by a numerical method that combines a Galerkin-finite element approximation in space and a finite difference approximation in time. This method yields results which compare favorable with an analytical solution for the one-dimensional, steady, vertical flow of hot water in a porous medium. Simulations of more realistic hypothetical problems involving transient, two-phase, two-dimensional (horizontal) flow

suggest that this approach is promising for the modeling of natural geothermal systems.

178 Federal Energy Administration, 1976, Strategic petroleum reserves. Final environmental impact statement for Bayou Choctaw Salt Dome: Dept. Interior, Federal Energy Adm., Strategic Petroleum Reserve Office, Washington, D. C., Rept. #FEA/S-76/501, 613 p.

Concerns the development of a 99 million barrel crude oil storage facility at the Bayou Choctaw salt dome. The site, a salt dome with existing cavities located in Iberville Parish, Louisiana, has been identified as a candidate site because it offers the advantage of large storage capacity, easy access to distribution network, and a relatively short preparation period. The site specific environmental impact statement analyzes the environmental impacts caused by site preparation and operation.

179 Federal Energy Administration, 1976, Strategic petroleum reserve, Bryan Mound Salt Dome: Dept. Interior, Federal Energy Adm., Strategic Petroleum Reserve Office, Washington, D. C., Draft Environmental Impact Statement, Rept. #FEA/S-76/347, 436 p.

This report is a site specific environmental impact statement (EIS) for the proposed storage of crude oil at the Bryan Mound salt dome located in Brazoria County, Texas. This project is part of the Strategic Petroleum Reserve (SPR) program mandated by Congress for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. This site-specific EIS analyzes the environmental impacts caused by site preparation and operation.

180 Federal Energy Administration, 1976, Strategic petroleum reserve, Cote Blance mine: Dept. Interior, Federal Energy Adm., Strategic Petroleum Reserve Office, Washington, D. C. Draft Environmental Impact Statement, Rept. #FEA/5-76-348.

This report is a site specific environmental impact statement for the proposed storage of crude oil at the Cote Blanche Salt Mine at Cote Blanche Island in St. Mary's Parish, Louisiana. This project is part of the Strategic Petroleum Reserve (SPR) program mandated by Congress for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. This report analyzes the environmental impacts caused by site preparation and operation.

181 Feely, H. W., and Kulp, J. L., 1957, Origin of Gulf coast salt-dome sulphur deposits: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 1802-1853.

Application of isotopic techniques, laboratory reactions, and bacteriological studies to determine that sulphate-reducing bacteria are the primary agents in the production of caprock sulfur. Dissolved sulfate is reduced to hydrogen sulfide by bacteria, after which part of this hydrogen sulfide is reoxidized to native sulfur by reaction with sulfate ions.

182 Fernelius, W., 1975, Production of fresh water by desalting geothermal brines--a pilot desalting program at the East Mesa Geothermal field, Imperial Valley, California (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract Volume, IX-3.

The Bureau of Reclamation is currently exploring the geothermal resources on the East Mesa of Imperial Valley, California. The purpose of the Bureau's research and development program is to determine the feasibility of desalting mineralized geothermal fluids. The practicability of concurrent generation of electric power will also be investigated. The additional fresh water developed in the Imperial Valley can be used to augment the flows of the Colorado River system.

Two test desalting plants, a multistage flash distillation unit, and a vertical tube evaporator distillation unit are being used to evaluate various procedures for desalting geothermal fluids. Each unit was designed to produce from 20,000 to 50,000 gallons of distilled water per day. Around-the-clock operations have been successful with no evidence of scaling or corrosion problems. Heat transfer tubes of various materials have been tested in the VTE unit. Presently double fluted copper-nickel tubes are installed and a full series of tests are being run. Test parameters consist of upflow and downflow modes of operation, feed fluid temperatures of 115°C to 160°C, tube diameters of 3/4" to 2" and lengths up to 6 meters. Feed flow rates of 5 gal/min to 50 gal/min liquid, and total flashdown characteristics from feed to blowdown.

183 Fincher, D. R., and Nestle, A. C., 1972, A review of corrosion monitoring techniques: AIME, Soc. Petroleum Engineers, Handling of Oil Field Waters, Symposium, Los Angeles, California, 4-5 December 1972, paper no. 4220, p. 27-40.

The search continues for new and better tools to monitor, measure, or detect changes both in the metal structure itself and in the rate of attack that the structure is experiencing. Several monitoring techniques are discussed. Each of the methods has certain advantages and disadvantages, and this paper reviews the practical application of all of these different techniques.

184 Fisher, P. W., 1970, Introduction to protective coatings: Norman, Univ. Oklahoma Corrosion Control Course, Proc., Sept. 14-16, 1970, 4 p.

Inorganic coatings are composed of metals or other noncarbon compounds. One example is the zinc used in galvanizing which controls corrosion by providing cathodic protection to the base metal until the zinc is consumed. Other types include plating with metals such as cadmium or nickel alloys which form a corrosion resistant surface for the base metal. Organic coatings are those which are compounds of carbon and include wax, asphalt, coal tar and plastics. This type of coating prevents corrosion by isolating the base metal from its surrounding environment by forming an impermeable and electrically insulating barrier. The National Association of Corrosion Engineers is preparing Recommended Practices for the application and inspection of coatings, and these should be published in the near future.

185 Fisher, W. L., Brown, L. F., Jr., McGowen, J. H, and Groat, C. G., 1973, Environmental geologic atlas of the Texas Coastal Zone--Beaumont-Port Arthur area: Univ. Texas, Austin, Bur. Econ. Geology, 93 p., maps.

The Environmental Atlas of the Texas Coastal Zone is designed to provide an urgently needed inventory for this most vital area of Texas. Presented is information on the nature of the Coastal Zone, what is happening to it, and at what rate changes are taking place. The basic environmental geology map delineates and depicts in detail resource units of first-order environmental significance. The accompanying series of eight special-use maps is designed for particular information needs. Included are physical properties and land use suitability, current land use, active physical processes, mineral and energy resources, land and submerged land topographic and bathymetric configuration, natural and artificial water systems, and climate. Statistical tables define and inventory the more than 250 natural and cultural features of the Texas Coastal Zone. A descriptive text explains the data presented, their utility, and means of extrapolating for other special uses.

Included in the map area are all of the Jefferson and Orange Counties and parts of neighboring Newton, Jasper, Hardin, Liberty, Chambers, and Galveston Counties, Texas.

186 Fisher, W. L., and McGowen, J. H., 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: Gulf Coast Assoc. Geol. Socs. Trans., v. 17, p. 105-125. Reprinted as Univ. Texas, Austin, Bur. Econ. Geology Geol. Cir. 67-4, 1967; Am. Assoc. Petroleum Geologists Bull., v. 53, no. 1, 1969, p. 30-54.

Regional investigation of the lower part of the Wilcox Group in Texas in outcrop and subsurface. The Rockdale delta system consisting of large lobate wedges of mudstone, sandstone, and carbonaceous deposits, is the thickest and most extensive of the lower Wilcox depositional systems. It grades updip to the thinner terrigenous facies of the Mt. Pleasant fluvial system. Deposits of the Rockdale delta system were the source of sediments redistributed by marine processes and deposited in laterally adjacent marine systems. Delineation of depositional systems and, more specifically, delineation of component facies of the several systems permit establishment of several regional oil and gas trends which show the relation of producing fields and distribution of potentially productive trends.

187 Fisher, W. L., McGowen, J. H., Brown, L. F., Jr., and Groat, C. G., 1972, Environmental geologic atlas of the Texas Coastal Zone--Galveston-Houston area: Univ. Texas, Austin, Bur. Econ. Geology, 91 p., maps.

The Environmental Atlas of the Texas Coastal Zone is designed to provide an urgently needed inventory for this most vital area of Texas. Presented is information on the nature of the Coastal Zone, what is happening to it, and at what rate changes are taking place. The basic environmental geology map delineates and depicts in detail resource units of first-order environmental significance. The accompanying series of eight special-use maps is designed for particular information needs. Included are physical properties and land use suitability, current land use, active physical processes, mineral and energy resources, land and submerged land topographic and bathymetric configuration, natural and artificial water systems, and climate. Statistical tables define and inventory the more than 250 natural and cultural features of the Texas Coastal Zone. A descriptive text explains the data presented, their utility, and means of extrapolating for other special uses.

This volume covers an area including most of Galveston County and parts of neighboring Brazoria, Chambers, Fort Bend, Harris and Liberty Counties, Texas.

188 Fisk, H. N., and McFarlan, E., Jr., 1954, Late Quaternary deltaic deposits of the Mississippi River (Local sedimentation and basin tectonics): Humble Oil and Refining Company, Explor. Dept., Geology Research Sec., October 1, 47 p.

This paper provides basic research on Quaternary sedimentary deposits located along the Central Gulf Coastal Plain and adjacent offshore areas.

The late Quaternary river mouth deposits of the Mississipp were laid down during the cycle of sea level change that has occurred since the beginning of the Late Wisconsin glacial epoch. Well data from the coastal Louisiana marshlands and the adjacent continental shelf, together with cores and samples from the Gulf floor, permit generalizations as to the nature, distribution, depositional history, and volume of these deltaic deposits. Carbon-14 analyses of wood and shells provide dates for younger deposits of the cycle.

More than 8,000 cubic miles of sediments have been carried to the Gulf by the Mississippi during the late Quaternary cycle. This huge mass has been deposited within a 44,000-square-mile area, comprised of the deltaic plain and adjacent portions of the continental shelf and slope. The continental margin has subsided during deposition, forming a trough-like depression which is localized to the depositional area. This trough has been downwarped more than 350 feet near the present shoreline and more than 500 feet offshore on the continental shelf.

189 Flood, B. S., Sangster, M. E., Sparrowe, R. D., and Baskett, T. S., 1977, A Handbook for Habitat Evaluation Procedures: Resource Publication. U.S. Fish and Wildlife Service, no. 132, 77 p.

The Habitat Evaluation Procedure Handbook has potental application to many projects being planned or constructed by various federal and state agencies. Handbooks such as this one strengthen the conceptual basis for evaluation procedures and will provide key habitat evaluation criteria to aid in implementation of these procedures. The objective was to provide a prototype to aid biologists in developing handbooks for other areas. Written criteria should foster uniformity in scoring since all team members will employ similar standards to evaluate each area. With such criteria, biologists unfamiliar with a project area may have a better basis to work from.

190 Food and Agriculture Organization of the United Nations, 1976, Inventory of data on contaminants in aquatic organisms: FAO Fisheries Circular no. 338, 169 p.

A listing of known contaminants in aquatic organisms and the name of the project to study the contaminant, the institution carrying out the research, location of the institution, the status of the project, and any details that are available. Includes data on freshwater, brackish water and marine areas.

191 Forbes, R. B., Leonard, L., and Dinkel, D. H., 1975, Total energy utilization potental of Alaskan thermal springs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, May 20-29 1975. Abstract volume, IX-4.

There are 95 or more thermal springs in Alaska. Based on geologic and geochemical data we do not know of any Alaskan thermal springs that are related to vapor dominated or large hot water reservoirs which have the potential for generating large amounts of electricity.

Heat is a precious commodity in the arctic and subarctic, and thermal springs are promising energy sources for rural Alaskan communities. Although small amounts of electricity could be generated from springs with higher flow rates and temperatures, utilizing Rankine Cycle-organic working fluid systems, non-electric applications show the greatest promise. An optimum total energy system designed for a small, isolated Alaskan village would generate a small amount of electricity (40-60 kw) with the subsequent extraction of energy for space heating, controlled environment agriculture, fish farming and hatchery operations and sewage processing and disposal. Phased experiments and pilot studies are planned for Manley, Clear Creek and Pilgrim Springs in 1975-77 to test the engineering feasibility of this concept.

192 Forgotson, J. J., 1969, Indication of proximity of high pressure fluid reservoir, Louisiana and Texas Gulf Coast: Am. Assoc. Petroleum Geologists Bull., v. 53, p. 171-173.

The writer suggests that a method is available to Gulf Coast operators for detecting the proximity of high-pressure fluid reservoirs. Use of this method may avoid costly blowouts or saltwater flows. Mud logging companies have reported that the presence of high background gas and high trip gas, together with lower than normal shale density, may signify the proximity of a high-pressure fluid reservoir. However, in many areas in the Texas-Louisiana Gulf Coast, low-density shales are not accompanied by other background gas or trip gas. Even the presence of low-density shale and low resistivity on an electric log does not indicate the proximity of such a high pressure fluid reservoir. It is concluded that a minimum increase of 200 percent in the shale penetration rate indicates that a high-pressure fluid reservoir is nearby.

193 Foster, J. B., and Whalen, H. E., 1966, Estimation of formation pressures from electrical surveys--offshore Louisiana: Jour. Petroleum Technology, v. 18, p. 165-171.

This paper presents a technique for estimating formation pressures from electrical logs. The technique has been found especially applicable in the offshore Louisiana area in detecting abnormally high reservoir pressures. After a brief review of the origin of abnormal pressures and the state of rock stress underground, it is shown that shale porosity is a function of net overburden pressure or effective rock fram stress. Data from electrical surveys are used to calculate formation resistivity factors (F), which are related to porosity. Formation factors are then correlated with net overburden pressure and the formation pressure is calculated, since formation pressure is the difference between total overburden pressure (1.0 psi/ft) and net overburden pressure.

Despite certain questionable features, the technique has been found to give reliable pressure estimates, and has been used in over 80 wells. Accuracy is usually within 5 percent. Several particular applications of the technique are listed. An alternate technique, similiar to that discussed in recent papers which utilizes only shale resistivity readings, is also discussed with a theoretical basis provided. This technique is simpler and quicker, though less reliable, than the primary technique.

194 Fowler, W. A., Jr., 1970, Pressures, hydrocarbon accumulation and salinities--Chocolate Bayou Field, Brazoria County, Texas: Jour. Petroleum Technology, v. 22, no. 4, p. 411-422.
The occurrence of abnormal pressures in this field is controlled by the distribution of permeable aquifers. Producing structural traps are related to pressure gradients in abnormally pressured reservoirs and to hydrodynamic flow across faults. Original formation water salinities are governed by flow across shale membranes. Present salinities are affected by water encroachment from other aquifers, and from nearby shales that compact as pressure declines. In an appendix is a calculation of flow rates over geologic time. Some useful figures are dip sections through the Chocolate Bayou Area and plots of pressure, salinities and lithology versus depth.

195 Franki, G. E., Garcia, R. N., Hajek, B. F., Arriaga, D., and Roberts, J. C., 1965, Soil survey of Nueces County, Texas: U. S. Dept. Agriculture, Soil Conserv. Service, 65 p., maps.
The Nueces County Soil survey contains a general soil map, a section describing soils series and surface features such as coastal dunes, gullied land and oil-waste land, and air photo coverage of the county. Use and management of soils is also given. There is a chapter on classification and factors of soil formation and on the general nature of the county.

196 Frazier, D. E., 1974, Depositional-episodes: Their relationship to the Quaternary stratigraphic framework in the northwestern portion of the Gulf Basin: Univ. Texas, Austin, Bur. Econ. Geology, Geol. Cir. 74-1, 28 p.
Discussion of problems concerned with proper correlations between the deep marine deposits and the shelfal and terrigenous deposits within the Quaternary section. The stratigraphic record yields evidence that each episode of clastic silicate deposition has been of limited duration and that each has been preceded and followed by a significant hiatus. Evidence for alternations of deposition and non-deposition is readily apparent in the landward portions of Pleistocene deposits along the Gulf Coast, due to the glacio-eustatic changes in sea level. Evidence of alternations, although elusive, exists also in the basinward portions of these depoists. The concept of depositional episodes explains the significance and relationship of these alternating conditions throughout the basin.

197 Futures Group, 1975, A technology assessment of geothermal energy resource development: Natl. Science Found., Contract C-836, U. S. Govt. Printing Office #038-000-00233-3, 554 p.

This report deals with some potential futures for geothermal energy in the United States, evaluates these, and makes recommendations based on these evaluations which can help policy-makers capture the desirable aspects of this energy source while avoiding its pitfalls. Because such considerations often involve a high level of uncertainty, the conclusions of this work necessarily depend on assumptions and judgments; therefore, the report documents the assumptions which were involved, separates opinion from fact.

198 Gagliano, S. M., Culley, P., Earle, D. W., King, P. and Latiolais, C. 1973, Environmental atlas and multi-use management plan for South-Central Louisiana: Louisiana State University Sea Grant Publication. (NTIS:COM-74-11819/1ST).

The Louisiana coast, dominated by the Mississippi River delta system, is exceptionally high in biological productivity. It can approximately be described as a self-maintaining natural system. Human activity has seriously altered the natural balance of this system. Massive environmental degradation has occurred during the past thirty years and the entire system may soon collapse. Primary causes of deterioration include: 1) flood control and navigation improvement; 2) mineral extraction; 3) accelerated subsidence; 4) urban encroachment into wetlands; and 5) water pollution.

199 Gagliano, S. M., Culley, P., Earle, D. W., Jr., Light, P., Rowland, A., Shlemon, R., van Beele, J. L., and Latiolais, C., 1972, Environmental atlas and multi-use management plan for south-central Louisiana: Baton Rouge, Louisiana State Univ., Coastal Management Studies, Center for Wetland Resources, 109 p., atlas.

Inventory of geological, geographical and ecological elements of the Terrebonne-Barataria Region. The text describes the work approach, natural setting and recommendations for future land-use management of the area. The atlas includes special-use maps showing distribution of soils, faults and salt domes, vegetation and biological areas, transportation, oil and gas fields, canals, precipitation, hurricanes, and salinity. Additional maps summarize an approach to management of the area.

200 Gaidry, W. J. III., 1974, Correlations between inshore spring White Shrimp population densities and offshore overwintering populations. Louisiana Wildlife and Fisheries Commission, New Orleans. Div. of Oysters, Water Bottoms and Seafoods. National Marine Fisheries Service Washington, D.C. L.W. & F.C. Technical Bulletin no. 12, (NTIS:COM-75-10271/5ST).

Biological sampling data obtained in January and February on offshore overwintering shrimp populations in the Ship Shoal to Trinity Shoal area were shown to correlate mathematically to the inshore spring

White Shrimp commercial landings of Terrebonne Parish and the total spring inshore White Shrimp commercial landings for Louisiana. Materials and methods for biological sampling, analytical procedures, and mathematical relationships are also presented.

201 Gaidry, W. J. III, and White, C. J., 1973, Investigations of commercially important penaeid shrimp in Louisiana estuaries: Louisiana Wildlife and Fisheries Commission, Division of Oysters, Water Bottoms and Seafoods, Tech. Bull. no. 8, 167 p.

Graphic and tabular data are presented on penaeid shrimp recruitment, growth, and movement. These parameters are related to hydrological conditions existing in the estuarine systems of coastal Louisiana. The relation between various hydrological conditions and their effects on penaeid shrimp production are also presented. Comparisons are made between the seven coastal areas in relation to life history functions of the two species of penaeid shrimp investigated.

202 Gallaway, B. J., and Strawn, K., 1974, Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas: Contr. Mar. Sci. Univ. Texas, v. 18, p. 71-137.

Biological and hydrological data were collected monthly from January 1968 to December 1969 at the P.H. Robinson Generating Station in Galveston Bay. It was found that fish appeared to be attracted to the discharge during all periods except the hot months when they generally avoided the immediate discharge area. A few fish were killed during the summer heat, and some avoided temperatures above 30°C, but more were abundant in waters up to 33-35°C. Some were found in temperatures up to 40°C. It was concluded that no detrimental effects were detected during the study except slight problems in June-September, when it was suggested that slight cooling of the discharge might be helpful.

203 Gallaway, B. J. and Strawn, K., 1975, Seasonal and areal comparisons of fish diversity indices at a hot-water discharge in Galveston Bay, Texas. Contr. Mar. Sci. Univ. Texas, v. 19, p. 79-89.

An up-bay control area, the direct discharge area, and a down-bay control area were compared in the vicinity of the P. H. Robinson Generating Station. Trawl and hydrological samples were taken at selected stations from January 1968 to December 1969. Results indicate marked seasonal differences in overall diversity or evenness between years and areas. Species richness for 1968 was higher than for 1969 and the discharge area had the greatest species richness compared to either control area. At water temperatures above 35°C in the discharge area, all indices declined.

204 Gaston, R.R., and Christianson, A.G., 1970, Beneficial uses of waste heat--An evaluation: Environmental Protection Agency,

Federal Water Quality Adm. Natl. Thermal Pollution Research Program, Pub. #EPl. 16:16130 FHJ 09/70.

There are a number of proposed beneficial uses of the waste heat contained in power plant cooling water.

As representatives of a regulatory agency, we are primarily concerned with solving the environmental pollution problem. Seen from this standpoint, a beneficial use must help reduce the thermal pollution problem directly or it must provide a profit to help offset the cost of cooling devices. Furthermore, the use must not result in additional pollution such as that resulting from untreated organic wastes.

Some uses, such as the culture of certain fishes, are now at the pilot program, or even commercial stage. Other uses, such as for industrial processes, require additional research. Integrated systems planned to produce steam as well as electrical power have been successful in special situations. In nearly all cases we need additional information on the overall economics of the proposed methods. This is especially true where high quality heat is taken directly from the power plant steam cycle for another use. Only with a complete economic analysis, including cost of distribution, waste treatment, etc., can we come to the final decision as to whether a "beneficial use" is truly beneficial in the long run.

205 Geagan, D. W. and Allen, T. D., 1961, An ecological survey of factors affecting fish production in Louisiana waters: Louisiana Wildlife and Fisheries Commisssion, 1961, p. 1-100.

This study attempts to determine the normal biological, chemical, and physical conditions which are related to fish production for representative lakes in Louisiana. It includes an evaluation of plankton, benthos, and fish population standing crop production plus fish stomach analysis. Pertinent physical and chemical characteristics are also reported. The four lakes studied are Caddo Lake, Caddo Parish; Cane River Lake, Natchitoches Parish; Chicot Lake, Evangeline Parish; and Lake Providence, East Carroll Parish.

206 Geertsman, J., 1973, Land subsidence above compacting oil and gas reservoirs: Jour. Petroleum Technology, v. 25, p. 734-744.

Considered in this paper are the causes of subsidence above hydrocarbon-producing reservoirs and a review of the state of the art of its prediction. A simple method is presented for estimating the order of magnitude of both compaction and the accompanying subsidence and procedures are given for measuring it in the field. It was concluded that oil reservoirs of the depletion type in loose sands, and extremely large gas reservoirs in either loose or friable rocks, are most sensitive to subsidence.

207 General Accounting Office, 1975, Problems in identifying, developing, and using geothermal resources: Report to the Congress by the Comptroller General of the United States, RED-75-330, 71 p.

This is a report to the Congress for considering funding levels and priorities for Federal programs designed to develop geothermal resources. Topics discussed are potential for developing large quantities of electric power from different geothermal sources, electrical power production systems, geothermal leasing programs and developing potable water from geothermal brines.

208 General Land Office, 1976, Current permitting processes in State and Federal natural resource agencies: Texas General Land Office, Texas Coastal Management Program, v. 1, 134 p.

The primary control technique employed by the state and federal governments for managing the natural resources of the coastal zone is the permitting process. Ten state and two federal agencies have permitting authority over the natural resources of the Texas coast. Each of these agencies has its own rules and regulations, and each uses its own formal and informal processes to reach decisions regarding the granting or denial of requested permits. In addition to these permitting agencies, the State Department of Highways and Public Transportation exercises authority over the Gulf Intracoastal Waterway.

Originally conceived as an internal working document for the Texas Coastal Managment Program (TCMP), this study presents the coastally relevant permitting procedures of all the state's natural resource agencies in order to review the existing governmental management authority over coastal resources.

The agencies chosen for analysis have ongoing direct regulatory authority on the Texas coast. Local, municipal, and county authorities were excluded. The agencies included in the study were: (1) Texas Air Control Board (TACB), (2) Antiquities Committee (AC), (3) General Land Office (GLO) in conjunction with the School Land Board (SLB), (4) Texas Department of Health Resources (TDHR), (5) Parks and Wildlife Department (P&WD), (6) Railroad Commission of Texas (RRC), (7) Harris-Galveston Coastal Subsidence District (HGCSD), (8) Texas Water Development Board (TWDB), (9) Texas Water Quality Board (TWQB), (10) Texas Water Rights Commission (TWRC), (11) U.S. Army Corps of Engineers (the Corps), (12) Environmental Protection Agency (EPA).

209 General Land Office, 1976, Current permitting processes in State and Federal natural resource agencies: Texas General Land Office, Texas Coastal Management Program, v. 2, 630 p.

This volume contains the rules of the 10 Texas state agencies listed in volume one most concerned with coastal matters and is intended as a ready reference for those concerned with the existing permitting authority of state agencies.

The material in this volume has been carefully prepared from official copies of the rules of each agency as filed with the Secretary of State.

This is not an official version of the rules and is intended solely to collect in one volume the rules which govern the issuance of permits for coastal activities. Most rules not concerned with the allocation of coastal resources have been omitted. The only official copy of state agency rules is maintained by the Office of the Secretary of State.

210 Gibbons, J. , and Sharitz, R. R., 1974, Thermal alteration of aquatic ecosystems: Amer. Sci. v.62, no. 6, p. 600-671.

Effluents from the Savannah River Nuclear Power Plant are cooled by a once-through system and discharged directly into the aquatic ecosystems with temperatures ranging from normal to above 50°C. The effects of heat on the river aquatic communities are described. Heated effluents may enrich or stress the ecosystem, depending on the biological feature being examined. The authors state that the potential for negative impact on aquatic environments must not be underestimated.

211 Gilmore, G. H., Ray, S. M., and Aldrich, D. V., 1975, Growth and mortality of two groups of oysters, Crassostrea virginica Grelin, maintained in cooling water at an estuarine electric power generating station. Texas A&M Sea Grant Pub., no. TAMU-SG-75-207, 67 p.

Growth and mortality of oysters with high and low levels of Labyrinthomyxa marina infections were measured in ponds receiving continuous flow of heated water from an electric plant, at the power plant intake and the discharge canal. Pond oysters had less cumulative mortality than intake or discharge oysters, regardless of infection. Only pond oysters gained in biomass by the end of the study. Intake oysters decreased in biomass in both the high and low infected studies. Oysters placed in the discharge canal during warm weather died within six weeks. Oysters held in the pond grew as well or better than oysters from natural reef areas in Galveston Bay.

212 Glass, W. A., 1975, Geothermal projects and estimates through 1985 and the year 2000: AIME, Soc. Petroleum Engineers, Practical Aspects of Drilling and Production Operations, Regional Mtg., Oklahoma City, March 24-25, 1975, paper SPE 5397, p. 57-62.

This paper examines various current and future aspects of geothermal energy production and utilization. The contribution of geothermal energy to the total present U.S. energy needs is 410 Mwe, or an amount of energy equivalent to less than 0.1% of U.S. daily oil consumption. If this very small output is to be significantly increased, an accelerated program ought to be implemented through speeded R & D and removal of institutional, regulatory and legal, environmental, and technological constraints. This would lead to an estimated output of 20,000 Mwe by 1985 and 200,000 Mwe by the year 2000. The geothermal projects that will contribute to this growth include dry steam fields, hot brines, moderate temperature/low salinity fluids, geopressured reservoirs, hot dry rock, and magmatic deposits.

213 Godwin, L. H., Haigler, L. B., Rioux, R. L., White, D. E., Muffler, L. J. P., and Wayland, R. G., 1971, Classification of public lands valuable for geothermal steam and associated geothermal resources: U.S. Geol. Survey Circ. 647, 9 p.

This report presents the classification standards for determining which Federal lands are classifiable as geothermal steam and associated geothermal resources lands under the Geothermal Steam Act of 1970.

Included is a copy of Public Law 91-591, 91st Congress, S368 "Geothermal Steam Act of 1970." (84 Stat. 1566)

214 Gosselink, J. G., Odum, E. P., and Pope, R. M., 1974, The value of the tidal marsh: Louisiana State University Sea Grant Pub., no. LSU-SG-74-03, 28 p.

Natural tidal marshes are evaluated in monetary terms. Including the value of byproduct production, aquaculture, waste assimilation, gross primary productivity, and a 5% interest, the estimated total social values are $50,000-$80,000 per acre. Some estuaries, such as the Potomac or the Hudson, are now performing waste assimilation work of even greater value, but such estuaries are overloaded to the point of degradation.

215 Greer, K. H., Blome, D. A., and Jones, J. E., Jr., 1976, A directory of computerized environmental information resources: University of Kentucky, Institute of Mining and Minerals Research Pub., no. IMMR23-GR3-76, 46 p.

This directory presents a selected listing of computerized environmental information resources. A description of each resource and listings of functions and services, subjects embraced, publications available, and mailing addresses are included. Subject areas are diverse and include such topics as pesticides, air pollution, soil data, energy, noise, oceanography, nuclear science and water, among others.

216 Griethe, H. P. and Lutkestratkotter, H., 1975, Injection of heated water into porous media: International Conference on Underground Waters, 3rd, and International Conference on Water Planning, 2nd, Paper, Palermo, Italy, November 1-5, 4 p.

The future restriction concerning discharge of thermal power plant cooling waters into water courses has led to the search for other cooling systems and media. A possible alternative method of distributing the heat into the environment is subsurface disposal.

217 Guiza, J., 1975, Power generation at Cerro Prieto geothermal field, Mexico (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-13.

The Cerro Prieto geothermal field is of the water predominant-type. Wells drilled to an average depth of 1300 m. produce a water -steam mixture in a weight ratio which varies from well to well from 0.5:1 to 4:1. Wells are cased with 298 mm and 196 mm diam. piping, with slotted casing at the bottom.

Separated steam is utilized in a 75,000 KW power station which is about to complete two years of operation. Extension of the same is underway to duplicate its capacity. Separation of the water-steam mixture is performed in cyclone Webre type separators which have demonstrated high efficiency as shown by the slight amount of deposits found on the turbine blades during the inspection after one year of operation.

Scaling of the wells have been experienced. Three low output wells are now out of the line and about to undergo cleaning. Separated water is now disposed to an evaporation pond. Problems encountered have not been insurmountable. The operation of the plant is a great success. Total potential of the Cerro Prieto field is yet to be known.

A new well drilled 1.5 Km northwest of the area under exploitation to a depth of 2000m has shown a bottom hole temperature of 344°C and a maximum discharge pressure of 77 Kg/cm^2(g).

218 Gunn, C. A., 1969, Annotated Bibliography of Resource Use. Texas Gulf Coast: Texas A&M University Sea Grant Publication, no. TAMU-SG-69-204, 387 p.

The information in the bibliography covers an area from the Louisiana border to the boundary with Mexico and covers a ribbon of land about 75 miles wide and that portion of the Gulf of Mexico within 10 1/2 miles of the coast. The time span of the sources dates from 1950 to 1969. Contains the annotated bibliography, an author list, city-county list, estuarine list, resource list, and a title word list.

219 Gunter, G., Ballard, B.S., and Venkataramaiah, A., 1973, Salinity problems of organisms in coastal areas subject to the effect of engineering works: Report to the U.S. Army Engineer Waterways Experiment Station by the Gulf Coast Research Laboratory, Ocean Springs, Mississippi, Contract Report, no. H-73-3, 176 p.

The relationships of all phyla of animals living in coastal waters are considered (reviewed) with particular reference to the Gulf and Atlantic Coasts. The report summarizes the influence of salinity on invertebrates, freshwater, marine, and euryhaline fishes and other vertebrates, and some aquatic plants. Examples are given of coastal works that cause salinity changes and their effects. Includes geographical considerations and contains an extensive literature section.

220 Gustavson, T. C., and Kreitler, C. W., 1976, Geothermal resources of the Texas Gulf Coast--Environmental concerns arising from the production and disposal of geothermal waters: Univ. Texas, Austin, Bur. Econ. Geology Geol. Circ. 76-7, 35 p.

Disposal and temporary surface storage of spent geothermal fluids and surface subsidence and faulting are major environmental problems that could arise from geopressured geothermal water production. Geopressured geothermal fluids are moderately to highly saline (8,000 to 72,000 parts per million total dissolved solids) and may contain significant amounts of boron (19 to 42 parts per million). Disposal of hot saline geothermal water in subsurface saline aquifers will present the least hazard to the environment. It is not known, however, whether the disposal of as much as 54,000 m^3 (310,000 barrels) of spent fluids per day into saline aquifers at the production site is technically or economically feasible. If saline aquifers adequate for fluid disposal cannot be found, geothermal fluids may have to be disposed by open watercourses, canals, and pipelines to coastal bays on the Gulf of Mexico. Overland flow or temporary storage of geothermal fluids may cause negative environmental impacts.

The magnitude of environmental impact of subsidence and fault activation varies with current land use; the greatest impact would occur in urban areas, whereas relatively minor impacts would occur in rural, undeveloped agricultural areas.

Geothermal resource production facilities on the Gulf Coast of Texas could be subject to a series of natural hazards: (1) hurricane or storm-induced flooding, (2) winds from tropical storms, (3) coastal erosion, or (4) expansive soils. Each has potential for damaging geothermal production and disposal facilites that could, in turn, result in leakage of hot saline geothermal fluids.

221 Hall, C. W., 1975, Federal regulation of injection wells, in Water: Am. Inst. Chem. Eng. Symposium Series, v. 71, no. 151, p. 292-306.

A synopsis of federal regulatory powers exercised by the EPA to safeguard the subsurface environment from pollution through the use of injection wells. The document, Administrator's Decision Statement #5 "EPA Policy on Subsurface Emplacement of Fluids by Well Injection," is included as Appendix A.

222 Hammond, W.W., Jr., 1969, Ground water resources of Matagorda County, Texas: Texas Water Devel. Board Rpt. 91, 163 p.

Ground water in Matagorda County occurs in several formations of differing ages but similar lithology. The formations are composed of interfingering beds and lenses of silt, clay, sand, and gravel, and function as a single water-bearing unit termed the Gulf Coast aquifer. Ground water moves through the aquifer at 10 to 20 feet per year from areas of recharge in and north of the county to areas of discharge in the Gulf of Mexico.

Use of ground water in the county has increased from 14 mgd in 1946 to 17 mgd in 1966, and water levels in wells are gradually declining in Matagorda County, especially in the western part. However, the present pumpage of 18,600 acre-feet per year (17 mgd) could be continued safely and economically indefinitely.

By proper exploration, well completion, and well spacing, ground water supplies can be developed with little danger of excessive water-level declines or changes in water quality caused by salt-water encroachment.

Numerous maps include those depicting the top of the fresh water and slightly saline water zones, the thickness and permeability of the water bearing formations, and location of salt water disposal pits and disposal wells in 1966. Records of selected water wells and drillers' logs are found in additional tables.

223 Hanck, J.A. and Nekoksa, G., 1975, Corrosion rate monitoring at The Geysers geothermal power plant (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-14.

At the Pacific Gas and Electric Company's geothermal plant, located at The Geysers in northern California, steam removed from the earth is piped directly to individual plant units where it is used to run low pressure turbines. This steam is later condensed in barometric or surface-type condensers after which it is used as cooling water. Inspection of several of the cooling systems showed severe localized corrosion in aluminum piping and some pitting on 316 stainless steel pumps and condensers. Corrosion monitoring equipment is being used at several of the power plant units to predict the life expectancy of the cooling system components. Each monitoring system includes corrosion test vessels, electrochemical probes, related measuring and recording equipment, and pipe-type corrosion coupons.

This paper discusses various corrosion mechanisms that have been encountered in the geothermal environment at The Geysers and describes the electrochemical polarization and electrical resistance techniques. Data reported include corrosion rates, pitting index and susceptibility as determined from potentio- and galvano-dynamic polarization curves, electrochemical probe potentials, water flow, temperature, and pH. Also discussed are the corrosion effects of different hydrogen sulfide abatement techniques and selection of corrosion inhibitors.

224 Hankin, J. W., 1975, Conceptual design and cost estimate for a 10 MWe (NET) power plant and experimental facility using geothermal brine resources (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-15.

A conceptual design and corresponding cost estimate were developed for a 10 MWe (NET) power plant and an experimental facility located at the same site. Typical site conditions at Heber, California, were used to develop and illustrate the concepts involved in the design.

The experimental facility was designed to serve as a test-bed for developing advanced geothermal processes, components and equipment using geothermal fluid under field operating conditions. Laboratories, test equipment and instrumentation were provided to meet the projected research and development needs for this type of resource over a wide range of experimental objectives. The energy conversion process of a 10 MWe (NET) power plant is based on a supercritical Rankine cycle using isobutane as the secondary (binary) working fluid. Major equipment includes seven heat exchangers (each 30' x 4.5' diam.), an 8000 gmp turbine driven isobutane feed pump, a 12.4 MWe turbine-generator, a desuperheater, two condensers (each 40' x 7' diam.), and a 330 x 10^6 Btu/hr evaporative cooling tower. The capital cost estimate was developed from the engineering drawings and equipment lists which delineate the coneptual design. Costs for final design, procurement, construction, and support activities were estimated based upon Bechtel experience in the design and construction of power plants.

225 Harbeck, G. E., Jr., Koberg, G. E., and Hughes, G. H., 1959, The effect of the addition of heat from a power plant on the thermal structure and evaporation of Lake Colorado City, Texas: U. S. Geol. Survey Prof. Paper no. 272-B, 51 p.

Lake Colorado City, a reservoir in north-central Texas, is used as a source of cooling water for a thermal-electric power-plant. Evaporation from the lake was determined by the energy-budget method for the period July 1954 to October 1955. Annual evaporation from Lake Colorado City was 93 inches, of which 85 inches was natural evaporation and 8 inches resulted from addition of heat to the lake by the power plant.

Analyses indicate that if no heat had been added by the power plant, the water-surface temperature would have been only 0.8°C lower than that observed. The temperature rise is almost directly proportional to the heat input, so that doubling the quantity of heat added by the power plant would raise the temperature an additional 0.8°C, if the volume of water in the reservoir was the same as in 1954-55. The temperature rise in a nearly empty reservoir, of course, would be much greater, and in a full reservoir, less.

The increase in evaporation from Lake Colorado City, when expressed as a volume, is directly proportional to the amount of heat added and is practically independent of reservoir contents. During 1954-55 the volume of forced evaporation resulting from the heat added by the power plant, 910 acre-feet, was almost exactly the same volume of water diverted to Colorado City for municipal purposes.

The entire lake is being effectively utilized in disposing of heat. Water temperatures in the lower basin of the lake were higher in winter than those in the upper basin of the lake; no appreciable differences were observed in summer. Density differences between the two parts of the lake were very small at all times.

226 Harder, A.H., Whitman, H.M. and Rogers, S.M., 1965, Methane in the fresh-water aquifers of southwestern Louisiana and theoretical explosion hazards: Department of Conservation, Louisiana Geological Survey and Louisiana Department of Public Works, Baton Rouge, Louisiana, 23 p.

Methane concentrations in fresh-water aquifers range from 0 to 127 ppm, with the higher concentrations occurring in the southern part of the Atchafalaya River basin and around some oil- and gas-producing fields. Concentration of methane in water wells varies with 1) their distance from the source of methane, 2) the length of time a well has been pumped, and 3) the pattern of pumping from nearby wells. In most of southwestern Louisiana the methane probably is generated from organic debris within the aquifers, however, it may also originate from oil and gas sands underlying fresh water aquifers.

A graph is presented relating the potential explosion hazard of methane to air space, pressure, temperature, and volume of water.

227 Hardin, F.R., and Hardin, G.C., Jr., 1961, Contemporaneous normal faults of Gulf coast and their relation to flexures: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 238-248.

Faults along which movement was contemporaneous with sediment deposition are common in the post-Eocene beds of the Gulf Coast. Faults of this type in the Gulf Coast are largely confined to a belt paralleling the coast line and located downdip from the Vicksburg (Oligocene) flexure. Since movement occurs contemporaneously with deposition, contemporaneous faults control sedimentation in areas affected by the movement. The attitude of the depositional surface of the downthrown fault block largely determines the distribution of sediments over the fault block.

A flexure is a zone downdip from which the rate of dip and thickening of sedimentary beds is accentuated. The writers believe that flexures result from deposition of sediments across the shelf break. Flexures affect most Cenozoic beds in the Gulf Coast, and most flexures are marked by contemporaneous faults of regional extent which tend to accentuate the effect of sedimentation. The prevalence of contemporaneous faults in post-Eocene beds is apparently related to the increase in rate of sedimentation and subsidence since the Cretaceous.

228 Harkins, K. L., and Baugher, J. W., III, 1969, Geological significance of abnormal formation pressures:Jour. Petroleum Technology, v. 21, p. 961-966.

The geological significance of abnormal pressures is illustrated by relating their occurrence to certain geological conditions with a specified time stratigraphic unit. The area studied is the Miocene Bigenerina unit located in offshore Louisiana, west of the Mississippi birds' foot delta. Useful figures include regional location of abnormal pressures. Occurrence of oil and gas associated with abnormal pressure is discussed.

229 Harmsworth, R. V., and Wahtola, C. H., Jr., 1975, Ecological effects of thermal discharge from power plants: Proc. of the 2nd World Congr. on Water Resources, Water for Human Needs, New Delhi, India, December 12-16, 1975. Pub. by Int. Water Resources Association, Indian Community, New Delhi, v. 5, p. 389-403.

This paper reviews the ecological investigations undertaken at the Point Beach Nuclear Power Plant on Lake Michigan, Wisconsin, United States. The ecological studies included thermal plume measurements on a biweekly basis and biological measurements on a monthly basis. The biological studies included the measurements of fish, plankton and benthic macroinvertebrate populations in the plume areas and reference areas outside of the plume. Analysis of variance between the plume and non-plume areas showed that there were no consistent significant differences that could be attributed to the thermal discharge.

230 Harrel, R. C., 1975, Water quality and salt water intrusion in the lower Neches River, Texas. Texas Jour. Sci., v. 26, no. 1 & 2, p. 107-118.

The effects of salt water intrusion, carrying with it toxic and organic waste effluents from the heavily industrialized lower reaches of the river are discussed. Salt water intrusion occurs for as much as 6 months of the year. During this period the water of the lower reaches of the river, and a distance of Pine Island Bayou becomes deoxygenated, and most of the organisms are killed by being trapped below temporary salt water barrier dams constructed to protect the freshwater intake of the Lower Neches River Valley Authority.

231 Harrel, R. C., Ashcraft, J., Howard, R., and Patterson, L., 1976, Stress and community structure of macrobenthos in a Fulf Coast riverine estuary: Contr. Mar. Sci. Univ. Texas, v. 20, p. 69 - 81.

The effects of salt water intrusion and industrial effluents are considered as they affect community structure of benthic macroinvertebrates in the Neches River estuary. Maximum numbers of species and densities occurred within the salt wedge. Estuarine species were common in upriver stations during salt water intrusion, and estaurine species made up 50% of the downriver station taxa. Diversity decreased downriver, ranging from 1.0 in the industrial region to 3.0 at the upriver stations. Includes a species list for each station and hydrological data for the sample area.

232 Harvey, W. W., Brown, F. C., and Turchan, M. J., 1976, Control of hydrogen sulfide emission from geothermal power plants: Newton, Massachusetts, EIC Corporation, #COO-2730-2, Energy Resources and Devel. Adm., Div. Geothermal Energy, 188 p. (Available from NTIS.)

A process for controlling H_2S emissions at geothermal power plants has been evaluated in laboratory scale equipment and by process engineering analysis. The process is based on scrubbing geothermal steam with a metal salt solution to remove selectively and precipitate the contained H_2S. The metal sulfide is roasted or oxygen/acid leached to regenerate the metal salt, and sulfur is rejected from the system as elemental sulfur or as sulfate.

Up to 95% removal of H_2S from simulated geothermal steams was obtained in a 2" diameter scrubbing column packed with 3 feet of 5/8" Flexirings by use of a recirculating slurry of copper sulfate/copper sulfide.

The results of preliminary corrosion tests or stainless steels are also given.

233 Hatle , Z., and Lampar, M., 1975, Exploitation of waste heat, in Environmental efficiency of cooling systems at nuclear power plants: Vienna, Austria, Internat. Atomic Energy Agency, Proc. Ser. STI/PUB/378, Symposium Proc., Oslo, Norway, 26-30 August, 1974, Paper IAEA-SM-187/47, p. 731-740. (Available from UNIPUB, New York).

About 2/3 of the heat generaged in producing electricity is lost to the environment. Waste heat can be decreased by the use of a combined power plant, producing heat and electricity, which will be used to supply large cities with heat and hot water. The produced heat would be distributed over a large area and the negative factors substantially lessened. Other applications include farming (greenhouses, soil heating, irrigation); cattle raising; mushroom growing; pond heating for intensive fish breeding; recreation purposes (heating swimming pools, increasing river temperatures, etc.); and drying vegetables and fruits.

234 Hawker, H. W., and Simmons, C. S., 1926, Soil survey of Willacy County, Texas: U. S. Dept. Agriculture, Bur. Chemistry and Soils, and Texas Agr. Exp. Sta., series 1926, no. 3, 57 p.

Includes information about the general nature of the county and a description of soil types. Some data is given on the content of water soluble salts in five-foot profiles. A general soil map is attached.

235 Hawkins, M. F., Jr., 1976, Investigations on the geopressure energy resource of southern Louisiana: Louisiana State University, Petroleum Engineering Dept., Review Rept., #ORO-4889-12.

The specific objectives of these researches were to make an estimate of the total geopressure energy (geohydraulic, geothermal and solution natural gas) in sandstone strata underlying southern Louisiana including those offshore water bottoms under state jurisdiction, and to locate one or more geopressured aquifers of such size and overpressure as to be of possible economic interest. Three geopressured aquifers have been located. Progress of the investigations are discussed and a series of statistical displays, computer maps and geological maps and cross-sections are given for two aquifers. Detailed geology on the third prospect will be given in a subsequent report.

236 Hayes, M. O., 1967, Hurricanes as geological agents, Case studies of Hurricanes Carla, 1961, and Cindy, 1963: Univ. Texas, Austin,

Bur. Econ. Geology Rept. Inv. 61, 56 p.

Tropical storms which cross the Texas coastline with a frequency of 0.67 storms per year play a major role in nearshore sedimentation on the south Texas coast. Greatest geological effects of these storms are produced by wind-driven waves and by storm surges.

The author compares the nearshore environmental complex before and after each hurricane, Carla and Cindy, to show the geological effects of the storms, including environmental mixing, sediment transport, and displacement of sedimentary processes.

237 Hearn, B. Carter, Jr., 1975, Geology of the Clear Lake volcanic field, California (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume II-22.

The 400-km^2 Clear Lake volcanic field, of Holocene to Late Pliocene (?) age, occupies the southern part of the partially fault-bounded Clear Lake topographic basin, about 150 km north of San Francisco. The Geysers geothermal production area is 1 to 6 km southwest of the volcanic field. The volcanic rocks unconformably overlie rocks of the Great Valley sequence and Franciscan Formation.

Basalt, andesite, dacite, rhyodacite and rhyolite occur as flows, domes, and volcaniclastic deposits in a complex sequence that is generally younger from south to north. Trends of magma composition with time show multiple cycles of basalt or andesite, through dacite or rhyodacite, to rhyolite, but rocks of intermediate composition are absent from some sequences. At least five distinct eruptive events produced rhyolite. Many normal faults trend predominantly northeast and north-northwest, approximately parallel to the San Andreas system. One such fault shows young strike-slip offset, indicating movement, if continuous, at an average rate of 1 mm/yr in the past 0.5 million years. Epicenters of felt earthquakes within the volcanic field and within the Clear Lake basin indicate active deformation.

A 25-mgal gravity low, 30 km in diameter, and a lobate resistivity low, 15 by 20 km, over the volcanic field can be interpreted as related to a subjacent partially fluid magma chamber. Repeated silicic volcanism, lack of welded tuffs, and lack of distinct large-scale caldera collapse suggest that the volcanic system is in an early evolutionary stage. The size and the distribution of thermal springs and wells infer that the volcanic field and its surroundings have considerable geothermal potential.

238 Heffernan, T. L., 1971, Port Bay--An evaluation of the habitat: Coastal Fisheries Project Report, 1971, Texas Parks and Wildlife Department, p. 63-91.

Trawl surveys of Port Bay (a tertiary bay of the Aransas Bay System) from December 1970 to November 1971 were utilized to evaluate the habitat. Consideration is given to below normal rainfall from November

1970 to July 1971 and the effects on White Shrimp and Blue Crab populations. The effects of Tropical Storm Fern are also discussed. Hydrological samples included salinity, temperature, turbidity, pH, dissolved oxygen, calcium, total hardness and magnesium which were correlated with population densities.

239 Heffernan, T. L., 1972, The effect of oilfield brine in the Mission River, Aransas Bay area: Coastal Fisheries Project Report, 1972, Texas Parks and Wildlife Department, p. 37-77.
Hydrological samples collected from December 1971 to November 1972 indicated that conditions were within the tolerance limits of the marine organisms inhabiting tertiary environments in the local area and that the loss of the Mission River as a nursery system was attributable to pollution from oil field brine. Oil field brine samples were analyzed at several stations and correlated with trawl samples of finfish, total and percent catches. White and Brown Shrimp were also collected at stations, and these data were correlated with salinity and temperature data.

240 Heffernan, T. L., Monier, J., and Page, S., 1971, Effects of oilfield brine on marine organisms. An ecological evaluation of the Aransas Bay area: Coastal Fisheries Project Report, 1971, Texas Parks and Wildlife Department, p. 209-227.
Brown Shrimp, White Shrimp, and Blue Crab megalops were utilized in bioassay procedures to determine effects of oilfield brine from sites emptying into Chiltipin Creek and Copano Bay. Control experiments were carried out and bioassays were performed at different percent brine solutions. Salinities of the brine ranged from 82.4 to 91.6 ppt. Brine concentrations of over 40% produced 100% mortality in all species tested.

241 Heffernan, T. L., Green, A. W., McEachron, L. W., Hammerschmidt, M. G., and Harrington, R. A., 1975, Survey of finfish harvested in selected Texas bays: Texas Parks and Wildlife.
Data include creel surveys of sport anglers in Galveston, San Antonio, Aransas Bays, and Upper Laguna Madre, as well as commercial fishery data for the same areas for 1974-1975. The data are reported for the important sports fish in total weight, percent catch, pounds per man hour, and seasonal catch per unit effort for each species.

242 Heffernan, T. L., Green, A. W., McEachron, L. W., Weixelman, M. G., Hammerschmidt, P. C., and Harrington, R. A., 1976, Survey of finfish harvest in selected Texas bays: NOAA and Texas Parks and Wildlife Department.
Data are derived from creel surveys or anglers in Galveston, San Antonio, Aransas, and the Upper Laguna Madre Bay areas from September 1974 to August 1975. Also includes a survey of the

commercial catch for the same period in the same bay systems. Data are presented as total catch, catch per man hour, average weight, and commercial harvest.

243 Herbich, J. B., and Schiller, R.E., Jr., 1973, Environmental effects of dredging: in San Pedro, California, Woodcon Assoc., 5th World Dredging Conference, Proc., Hamburg, Germany, June 11-15, p. 699-719.

This paper summarizes the present state-of-the-art of the effects of dredging on the environment. There are several possible advantageous effects of dredging on the environment including: removal of polluted bottom sediments for storage or treatment, advantageous change in flow patterns, reoxygenation of sediments and the water columns, and resuspension of nutrients. The possible deleterious effects include: removal or burial of habitats, change in the flow pattern, resuspension of polluted bottom sediments, and the creation of a barrier to movement of marine life. The needs for further research are delineated and the need to judge each proposed dredging operation on its own merits is pointed out.

244 Herrin, E., and Goforth, J., 1975, Environmental problems associated with power production from geopressured reservoirs, in Dorfman, M.H., and Deller, R.W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 311-318.

A look at the environmental problems that may arise in the exploration for and exploitation of geopressured reservoirs. A geothermal test facility in northwest Cameron County, Texas is used as a model. The most outstanding problems unique to this type of project are: 1) Disposal of water brought to the surface from the geopressured reservoirs, whether accidentally because of a blowout or purposefully as in a flow test; 2) Environmental changes brought about by the removal of vast amounts of high-pressure, subsurface water and the subsequent decrease in reservoir pressures.

Resultant adverse effects that are also very important are surface subsidence and possible inducement of earthquakes.

245 Hess, H., 1976, Geothermal energy prospects and limitations: Sierra Club Bull., Nov./Dec. 1976, p. 9-12.

Appraisal of geothermal energy as a fuel source now and for the future. Reference to Texas-Louisiana geothermal sources in this article is minimal.

246 Hill, R., 1971, Regulations of subsurface disposal in Texas, in Cook, T.D., ed., Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoir 18, Symposium Proc., Houston, Texas, December 6-9, p. 381-385.

Description of the steps one must take in order to obtain permission from the Texas government to dispose of wastes into the subsurface. Under the Injection Well Act, disposal wells should be constructed and maintained in such a way that ensures no other surface or subsurface body of water, or strata will be contaminated by the effluent.

247 Hill, R., 1972, Subsurface waste disposal in Texas: Texas Water Quality Board, Pub. 72-05., 40 p.
This document describes subsurface waste disposal in Texas utilizing injection wells. The first part is designed to inform the public of the practice and nature of the method and describes criteria used by the TWQB for determining whether reservoirs are suitable for injection, and for proper design and maintenance of injection wells. It also includes a sample application for a subsurface Waste Control Order. Useful figures include a very general map indicating suitability of areas of Texas for injection and a schematic of a typical industrial waste disposal well. Counties with waste disposal wells are tabulated.
Part two contains a copy of the Disposal Well Act.

248 Hindawi, I. J., Raniere, L. C., and Rea, J. A., 1976, Ecological effects of aerosol drift from a saltwater cooling system: Corvallis Environmental Research Laboratory, Oregon, Terrestrial Ecology Branch, 117 p. (NTIS:PB-258 831/7WP).
The local terrestrial effects of salt aerosol drift from powered spray modules and a mechanical draft cooling tower at Turkey Point, Florida were evaluated through field and controlled exposure studies. Indigenous vegetation, soil and fresh water were sampled over a year long period to acquire pre-activation baseline data and to provide for the assessment of possible environmental impact of salt aerosol loading from the test cooling devices. No measureable effects attributable to salt aerosol emissions from test cooling devices were detected in indigenous plants, soil or fresh water sampled during or following operation of the test cooling tower/spray modules. Full-term effects and salt aerosol tolerance levels of a cultivar plant, bush bean, were examined by controlled exposure to a simulated sea-salt aerosol at concentrations representative of the Turkey Point test site.

249 Hodges, A. L., Jr., Rogers, S.M., and Harder, A.H., 1963, Gas and brackish water in fresh-water aquifers, Lake Charles area, Louisiana: Louisiana Dept. Conserv., Geol. Survey, Water Resources Pamph. No. 13, 35p.
The presence of gas in the Chicot aquifer has caused some concern to water users regarding future utilization of fresh water in the Lake Charles area. The gas is in solution in the aquifers and will probably move with the water toward areas of heavy withdrawals. The amount of gas in water pumped from wells ranged from 0.0 to 100.6 cubic

centimeters per liter of water. Methane, the only hydrocarbon determined to be present, ranged from 0.0 to 82 ppm (parts per million). The normal background level of methane gas, as determined from measurements made in Calcasieu Parish, was 0.2 ppm; waters containing methane in excess of this concentration are considered to be methane enriched.

The occurrence of methane probably results from the generation of "marsh gas" in the aquifers. However, consideration is given to the possible movement of petroliferous gas through fault zones, abandoned holes, and blowouts.

High concentrations of methane occur in water from two zones in the Lake Charles area, one on the northeastern margin of Lockport oil and gas field and the other on the southeastern margin of the city of Lake Charles. Faulting associated with the Lockport salt dome has displaced the "200-," "500-," and "700-foot" sands of the Chicot aquifer and may provide pathways for the movement of gaseous and brackish water.

To obtain hydrologic and geologic data needed to determine the areal and vertical distribution of gaseous and brackish water, test holes were drilled and observation wells were installed at selected test sites. A gas-entrapment method and a combustible-gas meter were used to determine the amount of gas in the water.

250 Hoese, H. D., 1967, Effect of higher than normal salinities on salt marshes: Contr. Mar. Sci. Univ. Texas, v. 12, p. 249-261.

Salt marshes exist under the following conditions: 1) where salinities seldom fall below 30 ppt; 2) where waters are almost fresh; and 3) where salinity may exceed 40 ppt. Normally they occur where salinities range from 10-30 ppt. Increases in salinity may result in the salt-brackish-fresh water boundaries moving landward as they have in Louisiana. Increases in salinity often result in invasion of normally lower salinity areas by high salinity (marine) organisms, thus resulting in harm to the established fishery. There is little proof that primary productivity will decrease with increased salinity. The Gulf marsh system as based on Spartina alterniflora would probably be destroyed by salinities which approach or exceed 50 ppt.

251 Hofstetter, R. P., 1968, Oyster studies along the Texas Coast: Coastal Fisheries Project Report, 1968, Texas Parks and Wildlife Department, p. 23-33.

This study involved a survey of Crassotrea virginica in Aransas, Galveston and Matagorda Bays during 1968. The discussion includes the effects of salinity and siltation on mortality rates as well as the effect of Labyinthomyxa infection. Salinity-temperature data are tabulated and live versus dead oyster stocks are correlated with percent mortality.

252 Holland, J. S., Aldrich, D. V., and Strawn, K., 1971, Effects of temperature and salinity on growth, food conversion, survival and temperature resistance of juvenile Blue Crabs, *Callinectes sapidus* Rathbun: Texas A&M University Sea Grant Pub. no. TAMU-SG-71-222, 165 p.

The effects of temperature and salinity were tested in both caged and uncaged crabs. Growth yield and food conversion were determined in caged crabs. Lethal temperatures were tested in one group of animals; survival, sex and weight were recorded for these specimens. Growth and food conversion were found to be closely related to temperature. Optimal temperature was found to be 29-30°C. Yield and survival were also found to be influenced by temperature, but there were differences in caged and uncaged animals. Mortality was directly related to temperatures above 30°C. Low salinity (1.0 ppt) was lethal to small Blue Crabs at optimal temperatures. Salinities above 1.0 ppt had no significant effect on growth, yield, food conversion, or survival. The upper incipient lethal temperature of juveniles was 33°C.

253 Holland, J. S., Maciolek, N. J., and Oppenheimer, C. H., 1973, Galveston Bay benthic community structure as an indicator of water quality: Contr. Mar. Sci. Univ. Texas, v. 17, p. 169-188.

Five stations were sampled in different sections of Galveston Bay to determine the benthic community structure of each station. Species diversity, rarefaction curves, and probability of interspecific encounter indices were utilized to interpret the results in conjunction with hydrographic data and sediment analysis. Three of the stations exhibited normal estuarine water quality, while one of the others was stressed by natural causes (probably salinity fluctuations), and the fifth was intermittantly stressed by manmade pollution.

254 Holland, J. S., Maciolek, N. J., Kalke, R. D., Mullins, L. and Oppenheimer, C. H., 1975, A benthos and plankton study of the Corpus Christi, Copano and Aransas Bay systems. III. Report on data collected during the period July 1974-May 1975 and summary of the three-year project: Report to the Texas Water Development Board, 174 p.

Includes hydrographic, benthic, phytoplanktonic, and zooplanktonic data from 30 sites in the Corpus Christi-Aransas Bay system. Data was collected monthly for the period listed; previous collection data may be found in the following earlier reports:

1) 1973, Report on the methods used and data collected during the period September 1972 - June 1973, 122 p.
2) 1974, Report on data collected during the period July 1973 - April 1974, 121 p.

255 Holland, W. E., Smith, M. H., Gibbons, J. W., and Brown, D. H., 1974,

Thermal tolerances of fish from a reservoir receiving heated effluent from a nuclear reactor: Physiol. Zool., v. 47, no. 2, p. 110-118.

This report is concerned with comparing heat tolerances of Bluegill Sunfish subjected to heated effluent from a nuclear reactor with those of Bluegill living at normal temperature.

256 Holt, B., 1975, Conceptual design of a direct contact binary cycle power plant (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-17.

In conventional binary cycle power plant design, the working fluid is preheated, vaporized and super heated by the geothermal hot water in tubular heat exchangers. In the patented direct contact binary cycle design proposed in this paper, the working fluid is preheated, vaporized and superheated by direct contact with the geothermal hot water employing a counter-current column similar to the liquid-liquid extraction columns commonly employed in the chemical industry.

The expected advantages of this approach include the elimination of scaling on tubular surfaces by the geothermal hot water, the reduction in first cost and operating cost by eliminating the relatively expensive tubular exchanger, and the applicability of this cyle to high and low geothermal water temperatures and salinities. Soluble and entrained working fluid can be recovered from the reject geothermal hot water by flashing the hot water under vacuum. If noncondensables are present, the working fluid can be recovered by conventional vapor recovery systems employed in the petroleum industry.

A preliminary conceptual design and cost estimate of a demonstration plant is presented. The Federal Government plans to support the necessary research and development required to commercialize the direct contact binary process.

257 Hopkins, S.H., 1967, Biological and physiological basis of indicator organisms and communities (special contribution): in Olsen and Burgess, eds., Pollution and Marine Ecology, John Wiley and Sons, N.Y., p. 291-292.

A special note on the importance of identification of organisms and interpretation of results when utilizing indicator organisms. This section is an addition to the basic group of discussions on "Biological and Physiological Basis of Indicator Organisms and Communities," which includes the following sections: I. Oglesby, R.T., "Biological Basis," 267-270 p.; II. Wass, M.L., "Indicators of Pollution," 271-284 p.; III. Copeland, B.J., "Biological and physiological Basis of Indicator Communities," 285-288 p.; and IV. Oglesby, R.T., "Closing Remarks," 289-290 p. May be very useful background information.

258 Hornburg, C. D. 1975, Geothermal resource utilization: Paper and cane sugar industries: in Dorfman, M.H. and Deller, R.W., eds., Proceedings, First geopressured geothermal energy conference: Univ. Texas, Austin, Center for Energy Studies, p. 233-260.

Discusses the feasibility of utilizing thermal energy from spent geothermal fluids in pulp and paper mills and new sugar refineries. Concludes that it is technically sound and economically viable, provided that the other energy in the fluid (natural gas and pressure) are recovered concurrently.

259 Hornburg, C.D., and Morin, O.J., 1975, Geothermal resource utilization: Paper and cane sugar industries: U.S. Energy Resources Devel. Adm., Lawrence Livermore Labs. Final Rept., Contract #Z-7405-eng-48.

This comprehensive report analyzes the possibilities for use of geopressure resources found in the Texas-Louisiana Gulf Coast Region in industrial applications. In particular, the pulp and paper industries and the cane sugar milling and refining industries are examined.

Other industrial applications are: low level heat for petroleum refinieries, industrial organic chemical processing, and industrial inorganic chemical processing.

There is an analysis of waste disposal methods including well injection, discharge to surface waters, evaporation pond disposal, evaporation to dryness, and crystallization.

Maps show the location of pulp and paper mills in Texas and Louisiana, and the location of sugar refineries in Louisiana.

Figures include diagrams of a basic energy recovery system and geothermal energy consumption by pulp and paper processing systems, and cane sugar refining systems.

260 House, P.A., 1975, Potential power generation and gas production from Gulf Coast geopressure reservoirs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-18.

Extensive onshore and offshore zones of geopressured sand reservoirs are found in the Texas and Louisiana Gulf Coast region. Energy in these water reservoirs exists in the form of natural gas in solution, geothermal, and geohydraulic. Classes I, II, and III of reservoirs are defined with depths of 5000' - 10,000', 10,000' - 15,000', and 15,000' - 20,000'. Representative reservoir fluid temperatures and pressures are 200°F, 250°F, 300°F, and 5100 psi, 9100 psi, and

12800 psi respectively. Natural gas is presumed to exist at saturation levels. Economic analysis indicates that developed class I reservoirs would be profitable for gas production, classes II and III for combined power generation and gas production. A developed class III reservoir without the presence of gas would be a marginally profitable for electrical generation alone.

261 House, P. A., Johnson, P. M., and Towse, D. F., 1975, Potential power generation and gas production from Gulf Coast geopressured reservoirs, in Dorfman, M. H. and Deller, R. W., eds., Proceedings, First geopressured geothermal energy conference: Univ. Texas, Austin, Center for Energy Studies, p. 283-294.

Technological and economic assessment of the development of geopressure resources. Total flow, flashed steam, and binary cycle thermal energy conversion systems were investigated as a means to utilize geopressured geothermal energy. The total flow system was selected for a detailed power-plant systems analysis. Power plant net power output was determined for both surface and injection disposal of waste water.

262 Houston Lighting and Power Company, 197_, South Texas Project Units 1 and 2. Environmental Report vol. 1-7: Pages not numbered.

A report in the vein of an EIS on the effects of siting a nuclear power plant in the Texas Coastal region in Matagorda County. It may contain very useful information, but considerable effort may be required to extract it because the report is poorly organized.

263 Howard, J. H., and others, 1976, Geology and potential uses of the geopressure resources of the Gulf Coast Univ. California, U. S. Energy Resources Devel. Adm. Lawrence Livermore Lab. Contract #W-7405-eng-8.

The U. S. Energy Resources Development Administration has supported efforts to evaluate the potential contribution to the national energy supply of geopressured geothermal resources in the Gulf Coast. Efforts include a program of resource assessment and programs to examine utilization of the resource for the production of electricity and as a source of industrial-process heat. Work on resource assessment has suggested the presence of perhaps as much as 6,000 Mw-centuries of recoverable electric energy and 200 TCF of methane. This program has emphasized the finding of significantly large sand bodies within the geopressured stratigraphic section in addition to defining the distribution of abnormal fluid pressures and formation temperatures. Regional sand facies analyses conducted thus far indicate five locations in the Frio Formation of Central and South Texas where adequately large geopressured geothermal resources may be present. Engineering studies of energy-conversion systems based on total-flow, flashed-steam, and binary-cycle concepts show that development of electric power from the Gulf Coast geopressure resource is technically feasible. Study of use of the resource as process heat in pulp and paper mills and new sugar refineries has shown that these uses also are technically sound. The thermal content of a barrel of geothermal brine can coast as little as 9 mills when credited for recoverable hydraulic energy and methane. The value of heat approaches 50 mills per bbl for certain applications. All programs have pointed out clearly the need for better specific understanding of the resource, especially its dissolved methane content and its ability to produce for tens of years.

264 Hsu, S. A., 1976, Atmospheric dispersion characteristics in coastal environments: Louisiana State University, Coastal Studies Institute, 18 p. (NTIS:AD-A033 505/9WP).

Discusses the location of power plants in coastal environments and indicates that the major criteria for determinig such location are the following: 1) Offshore winds should be prevalent during most of the year, particularly during the summer; 2) the upwind coastal region should be relatively flat in order to avoid mesoscale turbulent vortex; 3) offshore bottom slope should be gently and bathymetrically uniform to attenuate storm surges and minimize wave effects.

265 Huang, B. K., 1974, An ecological systems approach to community noise abatement: Phase I: June, 1974, 110 p. (NTIS Report PB-234 311/9WP).

A noise-environment ecological system model is developed. Available traffic noise prediction models and simulation programs are evaluated. Computer graphic techniques are developed for quantitative identification of environmental noise levels and control. Surveys on noise attenuation characteristics of various plants, such as trees, shrubs and grasses have been performed to determine the effects of biological and physical parameters on noise abatement. Significant noise reduction is obtainable by properly selected shrub belts and grasses. Reverberation tests were conducted to investigate the absorptive reflection and sound scattering by vegetation to incorporate plant growth dynamics related to noise attenuation characteristics.

266 Hubbert, M. K., and Rubey, W. W., 1959, Role of fluid pressure in mechanics of overthrust faulting: I. Mechanics of fluid-filled porous solids and its application to overthrust faulting: Geol. Soc. America Bull., v. 70, p. 115-166.

Given sufficiently high fluid pressures, long fault blocks could be pushed over a nearly horizontal surface and blocks under their own weight could slide down very much gentler slopes than otherwise would be possible.

That these pressures exist is shown by observations made during recent decades in oil wells drilled in various parts of the world in which fluid pressures of the order 0.9 psi occur both in geosynclinal basins and in areas which are probably being compressed tectonically at present. It therefore appears that during periods of orogeny in the geologic past, which often have affected sedimentary sections many kilometers thick, the pressure in the water contained in large parts of these sediments must have been raised to, or approached, the limit of flotation of the overburden.

This is a good paper for the analysis of abnormal pressures and mechanical behavior of clays.

267 Isherwood, W.F., 1975, Gravity and magnetic studies of the Geysers - Clear Lake geothermal region California (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, III-43.

Gravity and magnetic fields in The Geysers-Clear Lake region are interpreted in relation to the known geology and other available geophysical data. New gravity data provide additional detail within the area of geothermal steam production. Computer techniques were used for removal of the regional gravity field, anomaly enhancement, and modeling sub-surface structures. The gravity field was separated into three components: 1) a regional field presumed to be due to deep crustal structure related to the continental margin; 2) a residual gravity low of approximately 30 mgal centered over Mount Hannah and having an approximate diameter of 20 km, which was modeled as being due to a magma chamber whose top lies within 10 km of the surface; and 3) a closed residual low over the original steam production field. This low is probably related to effects within 1.5 km of the surface and was modeled as a steam-saturated reservoir structure. Local magnetic highs correlate with surface outcrops of serpentinite and relief on the volcanic rocks. Upward continuation of the aeromagnetic data suggests that the serpentinite body along the Collayomi fault may extend to more than 3 km depth near Boggs Mountain, but that other serpentinite bodies are probably shallower. A long-wave length magnetic high (centered at -39°03'N 122°33'W) and a magnetic low (centered at -38°43'N 122°47'W) give half-width depth estimates of about 10 km. The center of the Mount Hannah gravity low lies in an area between these features and appears devoid of deep magnetic expression.

268 Israelsen, E.K., Bernard, D.R., Twedt, T.M. and Runke, H.M., 1975, A technique for predicting the aquatic ecosystem response to weather modification: Utah Water Research Laboratory, Logan. Office of Water Research and Technology, Washington, D.C., 163 p. (NTIS:PB-260 492/4ST).

In the past considerable effort has been spent on the development of techniques for increasing precipitation from a given cloud formation. However, little attention has been given to identifying and evaluating the impacts of cloud seeding activities on the aquatic ecosystems within the affected areas. The objective of this study was to apply the simulation technique to predict the impacts of cloud seeding on the aquatic ecosystems within the area subject to weather modification. A small mountain watershed near Logan, Utah, was selected for the study. Measurements were made of the significant parameter levels under current conditions. A hydrologic and water temperature model was calibrated to the watershed to predict the change in water temperature and stream velocities from arbitrary increases in the snowback. The predicted water velocities and temperatures were used to link the hydrologic system to the aquatic ecosystem which consisted of primary production, invertebrate, and fish communities.

269 Iyer, H.M., and Hitchcock, T., 1975, Seismic noise as a geothermal exploration tool: techniques and results (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, III-44.

Seismic noise measurements have been made by the U.S. Geological Survey at The Geysers, Imperial Valley, and Long Valley, California and at Yellowstone National Park, Wyoming. The noise surveys are done using a closely spaced group of stations recording for at least 48 hours and repeating the process in different parts of the geothermal area. One reference station is operated continuously. Several three-element arrays are also operated. Analysis techniques involve computation of average noise levels in several frequency bands using carefully selected noise samples and plotting their spatial variation. Power-spectra, cross-spectra, and azimuth and velocity of wave travel are also computed. In addition, in Long Valley, the seismic amplification of the soft sedimentary basin, the survey area, was estimated by comparing spectra of earthquake waves recorded by the basin stations with spectra at a reference station on hard ground.

The main results of the study are that: 1) high noise levels in the 1 to 5 Hz frequency band are found in all four geothermal areas; 2) the noise anaomalies associated with the Yellowstone geyser basins are certainly generated at depth and not by surface phenomena; 3) at the other geothermal areas presence of cultural noise makes it difficult to interpret the noise anomalies; and 4) the amplification of seismic waves by soft alluvial basins can partly account for the noise anomaly found in Long Valley. Experiments in many geothermal areas, and data analysis techniques that take into account non-geothermal parameters influencing seismic noise, are required fully to evaluate the usefulness of seismic noise as a geothermal exploration tool.

270 Jackson, H. W., 1972, Estuary Studies (161. 3). Training manual: Environmental Protection Agency, Cincinnati, Ohio. Office of Water Program Operations, 138 p. (NTIS: PB-238 482/4ST).

The report includes a collection of expanded basic outlines that deal with the estuarine environment to be used for course studies. These include: 1) origin and hydrology of estuaries; 2) geological studies; 3) chemical dynamics of estuaries; 4) estuarine biology; 5) and estuarine pollution.

271 James, R., 1975, Optimum well-spacing for geothermal power (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-19.

The closer the distance apart of production wells the lower the field development cost due largely to the high price of steam transmission lines. For underground systems where flow is through fissured formations, it is found that wells of fairly large discharge can be quite close together (order of 50 m) without interaction effects. Calculations indicate that this applies to both hot water fields and to those tapping dry steam reservoirs. Hence well-spacing for a hot water system should still be appropriate if discharges changed to dry steam.

272 James, R., 1975, The applicability of the binary cycle (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-19.

Because of declining reservoir pressure under exploitation, a geothermal power project has to be designed for an operating well-head pressure which falls to as low as 70-80 psia during the economic life of the scheme. This rule applies equally to a binary cycle as to a conventional two-stage flash cycle based on a pressured hot water reservoir. Such a comparison reveals that the thermal efficiency of the binary cycle is less than that of the conventional system, due to the low temperature of the flashing primary fluid entering the heat exchanger. This result would be reversed, however, with the development of a successful deep well pump which would pressurize the primary fluid so that its temperature on entering the heat exchanger is as high as that of the deep reservoir.

273 Jessen, F. W. and Roshausen, F. W., 1944, Waters from the Frio Formation, Texas Gulf Coast: Am. Inst. Mining and Met. Engrs. Trans., v. 155, p. 23-38.

It is the purpose of this paper to present data on brines occurring in the Frio formation of the Texas Gulf Coast, and to show how their composition varies, (1) with depth below the surface, (2) with depth below the top of the formation, and (3) along the approximate strike.

The brines vary in chloride content from 3,180 to 73,000 ppm, though the average salinity of the salt waters is shown to vary with total depth; the concentration being 35,000 to 40,000 ppm at 3500 to 5500 ft., slightly less than 50,000 ppm chloride at 5500 to 6500 ft. and average 38,000 to 40,000 ppm below 6,500 feet.

From the analyses available, it appears that the highest concentration of salts occurs in the upper 300 ft. of the formation, while lower salinity is found with increasing depth below this point.

The salt waters from wells in Starr County show less concen- of dissolved salts than in any other group of wells farther north along the strike.

In all, 116 analyses from 63 fields and 14 wildcats, from depths ranging from 1300 to 11,400 ft. below the surface and from 2 to 3240 ft. below the top of the Frio, are recorded.

274 Johnson, R. B., Jr., 1974, Ecological changes associated with industrialization of Cedar Bayou and Trinity Bay, Texas: Texas Parks and Wildlife Techn. Ser., no. 16, p. 1-79.

Discussion of the ecological effects of industrialization on two areas in Galveston Bay. Cedar Bayou is a discharge site for U. S. Steel and a Houston Power and Light generating station, and is also receiving oilfield and LPG brine contamination. Trinity Bay is a discharge site for thermal effluents from a power plant and receives freshwater inflow from the Trinity River. Includes the effects of these effluents on temperature and salinity and correlates these parameters to the occurrence and distribution of fishes, shellfish and vegetation in the area.

275 Jones, E. E., 1975, The vital role of protozoa in Mobile Bay: Report to the Office of Water Research and Technology, Washington, D. C., by Auburn University and the University of South Alabama, 16p. (NTIS:PB-240 171/9ST).

Describes protozoa as the basal animals in the animal food web, feeding on both bacteria and unicellular green plants and thus they are the lowest point at which plant material is converted into animal material. With a constant inflow of fresh water. nutrients, pollution, and tidal saline waters from the Gulf of Mexico there is a constant mixing of fresh water and marine forms in Mobile Bay, and it becomes apparent that protozoa are essential to the Bay's productivity.

276 Jones, J. A., 1968, Primary productivity by the tropical marine Turtle Grass, Thalassia testudium Konig, and its epiphytes: PhD. Dissertation, University of Miami, 196 p.

Contains a good discussion of the importance of Thalassia to the coastal shallow waters of South Florida. The variables which affect growth and productivity are covered in detail as well as the epiphytic communities which associate with Turtle Grass. A very useful reference and may be directly related to the Texas Gulf Coast.

277 Jones, L. L., and Warren, J. P., 1976, Land subsidence costs in the Houston-Baytown area of Texas: Am. Water Well Assoc. Jour., Pt. I, November, p. 597-599.

Pumping of groundwater has caused subsidence of as much as 9 ft. in the Houston area. Costs for this water have not included damages caused by the subsidence. In this paper an economic model is developed based on damages reported on questionnaires and in interviews in a survey of 300 sq. mi. in the Houston-Baytown area of Texas.

Most costs and losses associated with subsidence were found to be caused by temporary or permanent tidal or freshwater flooding. The model reveals that the substitution of surface for ground water use in the area would provide a lowest-cost alternative for water supply. Total costs of water for the area are minimized by not permitting groundwater withdrawal beyond the point where subsidence would begin to occur.

278 Jones, M. B., 1975, Synergistic effects of salinity, temperature, and heavy-metals on mortality and osmoreregulation in marine and estuarine isopods (Crustacea): Mar. Biol., v. 30, no. 1, p. 13-20.

The effects of cadmium, zinc, and lead on mortality and cadmium, zinc and mercury on osmoregulation, were recorded for species of marine and estuarine isopods. These effects were tested at different concentrations of seawater and under varying temperatures. Differences were noted in the responses of the estuarine and marine forms.

279 Jones, P. H., 1969, Hydrodynamics of geopressure in the northern Gulf of Mexico basin: Jour. Petroleum Technology, v. 21, no. 7, p. 803-810.

Discussion of genetic processes resulting in the formation of geopressured zones in sediments. This paper presents a very good overview of hypotheses and research on abnormally pressured sediments to date. Tables include listing of geopressured aquifers in southern Louisiana and adjacent areas, and geostatic ratio and composition of formation waters in geopressured aquifers of Texas and Louisiana.

280 Jones, P. H., 1975, Geothermal and hydrocarbon regimes, northern Gulf of Mexico basin: in Dorfman, M. H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 15-19.

Geothermal heat flow in the Gulf basin is primarily a function of its hydrology. Water expelled from sediments with deepening burial and increasing overburden load escapes upward and toward the basin margin. Where it moves freely in the hydropressure zone, the basin is relatively cool; but where rapid sedimentation and contemporaneous faulting have retarded water loss from compacting sediments, the interstitial fluid pressure reflects a part of the overburden loan, and the formation waters are superheated and geopressured. The geopressured zone is common below depths of about 3 km (9,600 ft.) in the basin, beneath an area of 375,000 km^2 (150,000 mi^2), and extends downward perhaps 15 km (50,000 ft.) to the base of Cenozoic deposits.

The upper boundary of the geopressured zone is the most important physical interface in the basin. Across it the head of formation water increases downward from a few hundred to several thousand feet above sea level; the geothermal gradient increases downward from 20° to 40° C/km to 100° C/km or more; the salinity of formation water decreases downward, commonly by 50,000 mg/l or more; and the porosity of shale and sand increases downward by 10 to 25 percent.

281 Jones, P. H., 1975, Geothermal and hydrodynamic regimes in the northern Gulf of Mexico Basin (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume II-23.

Heat flow and geotemperature in the upper part of the earth's crust are primarily functions of mass transfer, solid and/or fluid. The factors which control the occurrences and rates of mass transfer define the geothermal regime in space and time.

Downward intrustion of the crust by sediment that formed the Gulf Coast geosyncline during the Cenozoic, and contemporaneous upward intrusion of the sediment fill by hundreds--perhaps thousands--of salt diapirs from an underlying Mesozoic evaporite bed are the dominant elements of rock mass transfer in the Gulf basin. Delayed and retarded release of interstitial, intracrystalline, and bound water in the Cenozoic sediments, controlled by the thermophysical and thermochemical properties of sediment minerals and the effects of structural deformation and sediment facies distribution, are the most important factors in the geothermal regime of the basin.

Prograding alluvial and deltaic systems built gulfward from the northwestern margin of the basin in eight major cycles of fill during the Cenozoic. The sandy deltaic deposits overloaded the underlying fine-grained sediments, and sank into them as their waters were squeezed out. Major shear zones (contemporaneous faults) developed at the underlying facies boundaries, and offset sand-bed aquifer systems were compartmentalized and geopressured.

282 Jones, P. H., Hendricks, E. L. and Trelan, B., 1956, Water resources of southwestern Louisiana: U.S. Geol. Survey, Water Supply Paper 1364, 460 p., maps.

This report encompasses the contents of the publication "Geology and ground water resources of Southwestern Louisiana," (Jones, et al., 1954). In addition to this, discussions of surface water resources and the quality of water in southwestern Louisiana are given.

The surface water investigation includes determination of the volumes of stream flow available and the volumes of water directed for irrigation from three principal streams, the Vermilion, Mermentau and Calcasieu Rivers. Movements of salt water from the Gulf of Mexico into the streams during periods when withdrawal exceeded fresh-water supply are delineated. Water requirements for growing rice are shown.

The quality of water is reported as the amounts and kinds of minerals present in well and stream waters at various times, places, and depths to determine the fitness of the waters for various uses. The report contains tables of temperatures and chemical analyses of water samples collected from wells and daily sampling stations on the rivers. During periods of salt-water encroachment, area-wide stream surveys and special surveys were made to determine salinity changes. Movement of salt water in the Vermilion and Calcasieu Rivers is discussed in detail.

There is also a section on the rice industry, and a suite of maps showing several features related to the geology, physiography and hydrology accompany the paper.

283 Jones, P. H., Turcan, A. N., Jr., and Skibitzke, M. E., 1954, Geology and ground-water resources of southwestern Loisiana: Louisiana Geol. Survey Geology Bull. no. 30, 285 p., maps.

In southwestern Louisiana large quantities of fresh ground water are available for agricultural, municipal, domestic, and industrial purposes. However, local and regional problems resulting from salt-water encroachment in coastal streams and persistent declines of the ground water levels in certain areas during drought periods have caused some concern regarding the future water supply of the region.

Southwestern Louisiana is underlain by a vast deposit of sand and gravel which yields very large quantitites of water to wells (> 600,000 acre-feet annually). The best aquifers (water-bearing formations) generally range in thickness from 200 to 600 feet. The aquifers have a gentle gulfward slope, and are exposed to rainfall and recharge from streams in the broad rolling uplands north of the rice farming area.

Ground water levels fluctuate seasonally. However, many wells in Southwestern Louisiana have shown a downward trend, the net decline being less than 10 feet in the most seriously affected areas for the past nine years.

Ground water resource information in this paper includes studies of individual reservoirs and of salt water encroachment. A table of chemical analyses of water samples collected from representative wells is included in this report along with a discussion of important chemical-quality characterics of the waters. A suite of twenty-seven maps showirg general features related to the geology, physiography and hydrology the paper.

284 Juneau, C. L., 1975, An inventory and study of the Vermilion Bay-Atchafalaya Bay complex: Louisiana Wildlife and Fisheries Commission, Division of Oysters, Water Bottoms, and Seafoods, Tech. Bull., no. 13, p. 1-153.

The Vermilion Bay-Atchafalaya Bay estuarine complex is a vast open water brackish system whose primary sources of freshwater are the Atchafalaya and Vermilion Rivers. There are approximately 475,000 surface acres within the system. Vegetation in the complex varies from fresh to brackish, depending on nearness to the mouth of the Atchafalaya River. Vegetation near the river is almost totally fresh while that farther to the west consists mainly of brackish plant species. Included in the report are tabular data on river discharge, coastal population statistics, and sources and quantities of industrial waste discharged into the system.

285 Kadlec, J. A. and Wentz, W. A., 1974, State-of-the-art survey and evaluation of marsh plant establishment techniques: Induced and natural. Volume I. Report of research: University of Michigan, Ann Arbor. School of Natural Resources. Army Engineer Waterways Experimental Station, Vicksburg, Miss. Coastal Engineering Research Center, Fort Belvoir, Va., 271 p. (NTIS:AD-A012 834/8ST).

Knowledge of marsh and aquatic plant establishment was assessed by reviewing the literature and contacting agencies and individuals likely to have relevant information. Factors that affect plant establishment in saltwater areas include tides, salinity, drainage, water table, rainfall, soil evaporation, temperature, biota, water depth, light penetration, and current and wave action. In freshwater areas water levels or depths, substrate, water quality, turbidity, and currents, and wave action are particularly important to place establishment. By controlling various environmental factors, it is possible to promote and encourage the natural invasion and growth of aquatic and marsh plants, especially in freshwater systems. In many cases, plantings of aquatic and marsh plants will be necessary to vegetate a new substrate. Seeding appears to be the least expensive procedure, but environmental conditions must be favorable or success will be low. Transplants usually provide faster establishment and are hardier than seedlings.

286 Keefe, C. W., 1972, Marsh production: a summary of the literature: Contr. Mar. Sci. Univ. Texas, v. 16, p. 163-181.

Reviews studies on freshwater and saltwater marsh production. Discusses the unusually high rates of production in these communities as compared to terrestrial and phytoplankton communities. The role of marsh plants as food for consumers is also discussed. Physical parameters such as temperature and salinity, as well as nutrient levels and energy flow are considered. Contains an extensive and useful bibliography.

287 Keith, D. E. and Hulings, N. C., 1965, A quantitative study of selected nearshore infauna between Sabine Pass and Bolivar Point, Texas: Pub. Inst. Mar. Sci. Univ. Texas, v. 10, p. 33-40.

The effects of substratum and season were studied at five shallow sublittoral stations between Sabine Pass and Point Bolivar from September 1962 to September 1963. Certain species were designated as diagnostic of sand or mud. All of the diagnostic species were found to have some degree of seasonal variation. Hurricane Cindy had very little effect on the organisms living in sand, but had drastic effects on those occupying mud bottoms. The optimum depth below the surface occupied by most species was 1 to 2 inches.

288 Kerr, P. C., Paris, D. F., and Brockway, D. L., 1970, The interrelation of carbon and phosphorus in regulating heterotrophic and autotrophic populations in aquatic ecosystems: Federal Water Quality Administration, Athens, Georgia, National Pollutants Fate Research Program, 60 p., (NTIS:PB-195 195).

Laboratory and field investigations were conducted on the fate and cycling of carbon and phosphorus in selected aquatic ecosystems. Inorganic carbon, as CO_2, supplied by both bacterial cultures and cylinder gases, stimulated the growth of the blue-green alga *Anacystis nidulans.* Diel studies on a stream which received biologically-treated sewage demonstrated that the dissolved CO_2 and HCO_3 continually produced in the system were essentially depleted by the autotrophic organisms during daylight hours, while the concentration of phosphorus remained unchanged. Addition of organic carbon and inorganic nitrogen and phosphorus alone and in combination to the waters studied directly stimulated the oxidation metabolism of the heterotrophic population, which resulted in increased dissolved CO_2 and HCO_3. This increased availability of inorganic carbon, rather than the direct metabolic removal of dissolved phosphorus by the algae, appeared to be directly responsible for the growth of the algal populations in the waters studied.

289 Kharaka, Y. K., Callender, E., and Wallace, R. H., Jr., 1977, Geochemistry of geopressured waters in the Gulf Coast region of Texas: Geology, v. 5, no. 4, p. 241-244.

Detailed chemical analyses of 54 formation water samples from the Frio Clay in 11 oil and gas fields in the Houston-Galveston and Corpus Christi, Texas areas show that the salinity of water in the geopressured zone ranges from about 20,000 to 70,000 mg/l dissolved solids. Samples from many gas wells give low salinities that are not representative of the true salinity of formation water because of dilution by condensed water vapor produced with natural gas. Quartz and Na-K-Ca geothermometers are used in conjunction with the measured subsurface temperatures to identify the diluted samples and to estimate their true salinities. Better understanding of the geochemistry of geopressured geothermal waters is needed to minimize the problems associated with their use as a source of energy.

290 Kier, R. S., Garner, L. E., and Brown, L. F., Jr., 1977, Land Resources of Texas: Univ. Texas, Austin, Bur. Econ. Geology, in press, maps.

Texas is endowed with an enormous variety of natural land resources. Because of this great diversity, Texas exhibits a natural variability in energy and mineral resources, agricultural capacity, environmental sensitivity and recreational potential that promotes industrial and cultural attraction. Essential to achieving balanced use of the environment is a comprehensive knowledge of physical, chemical, and biological characteristics limiting conditions and interrelationships of the varied land and water areas in Texas.

This publication provides an inventory of Texas lands. Seventy-one land resource units, recognized by unique combinations of substrate materials, soils, vegetation, topographic configurations and active processes are depicted on a map at a scale of 1:500,000. A table on the map presents natural suitability and recommended use of these units. Additional tables in the text give more specific information about resource units such as physical properties, distribution, substrate composition, plants and animals, economic resources, and current land use. There are 11 small auziliary maps that summarize aspects of land resources in Texas that could not be shown on the large map.

The map provides the regional perspective of Texas lands that is needed to appraise the kind and level of technology required to use Texas lands in a manner that is economically prudent and environmentally compatible with natural conditions.

291 Kihara, D. H., 1975, Working fluid selection and preliminary heat exchanger design for a Rankine cycle geothermal power plant (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-20.

There have been proposals for geothermal power plants using a Rankine cycle with a low boiling point fluid as the working fluid. In this study a list of possible working fluids with wide ranges of property values is examined, and two, isobutane and R-114 are selected as being representative of the type of working fluid that might be selected by plant engineers.

Heat exchangers will be at the interface between the geothermal fluid and the working fluid and will constitute an essential component of this particular means of energy conversion. A parametric study is conducted of a vertical, counterflow, shell and tube heat exchanger designed for use in a 10 MW geothermal power plant which utilizes geothermal brine at moderate temperatures.

The computational procedure for determining the required brine flow rate, tube lengths, number of tubes and pressure drops is outlined. Detailed in graphical form are results showing how these parameters are affected by changes in brine inlet temperature, turbine inlet temperature, scale thickness and system pressure.

292 King, C. H. and Ward, G. M., 1974, Perimeter canal; A new approach to discharge urban water into a coastal mangrove area, in

Selected Papers, agricultural and urban considerations in irrigation and drainage: Am. Soc. Civil Engineers, Spec. Conf., Fort Collins, Colorado, August 22-24, p. 99-129.

The paper discusses the drainage facility in terms of its application to a 74-square mile watershed in the western coast of Florida. This waterway will perform important environmental functions in collecting and allowing restricted, biologically screened discharge of the upland runoff. By collecting and restricting the upland runoff until deleterious components can be assimilated by natural vegetation, the perimeter waterway conceivably may improve water quality. The waterway will also act as a physical buffer between the developed and undeveloped areas in addition to being a functioning part of the ecosystem. Through design, the west edge of the waterway will maintain simulated sheet flow through the mangroves and grasses. Based on present observations, the mangroves will flourish in the nutrients and sediments deposited by the runoff, and the net productivity in life chain cycle is expected to increase.

293 Kinne, O., 1967, Physiology of estuarine organisms with special reference to salinity and temperature: general aspects: in Lauft, G. H., ed., Estuaries, Amer. Assoc. Advanc, Sci. Pub., no. 83, Washington, D. C., p. 525-540.

A good review of knowledge of the effects of temperature and salinity on the physiology of estuarine organisms. With respect to salinity, regulation and reduction of contact appear to be the most important responses. With respect to temperature, acclimation represents the essential means for compensation. Apparently the compensatory means for adverse salinity conditions are more immediately available and better developed than those for temperature.

294 Kleeman, W. T., Haynes, K. E., and Freeland, T. F., 1975, The technical assessment of the impact of geopressure development in the Corpus Christi area of Texas, in Second United Nations Symposium on the development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, p. 2389-2402.

This study is an outgrowth of a four year ongoing N. S. F. (RANN) project on the impact of alternative environmental policies on coastal zone development in the Corpus Christi area of Texas. In recent years geothermal development has become a distinct possibility in the vicinity of the study due to the identification of a belt of geopressured sands in the immediate off-shore area.

The economic interrelationships between alternative environmental policies and the development of a nearby geothermal energy source are examined. This examination is based on a localized version of the Texas

Input-Output model and information generated from the environmental policy impact analyses.

In addition to the impact on output there are also changes in the rates of migration, expansion and location of housing, and the location of economic activity.

295 Kleerekoper, H., 1976, Effects of sublethal concentrations of pollutants on the behavior of fish: Jour. Fish. Res. Board Canada, v. 33, no. 9, p. 2036-2039.

Due to dilution and dispersion of pollutants in the natural environment, chronic exposure to subacute concentrations of such substances is likely to affect a much larger number of species and individuals than exposure to acutely morbid or lethal concentrations. Evidence points to be the behavioral toxicity of subacute concentrations of pesticides affecting general locomotor behavior and orientation responses to environmental variables. Complex interaction of these variables also may occur, and the response to such interaction by fish may be affected by chronic exposure to organophosphate. Response modifications are often subtle and may require long-term monitoring.

296 Kleway, L. M., Petering, H. G., and Stemmer, K. L., 1971, Controlled environment for trace metal experiments on animals. Environmental Sci. and Technology, v. 5, p. 1196-1199.

The construction of a laboratory for study of the effects of metallic element exposure on small mammals is described. Absolute exposure control was obtained by careful attention to structural materials, air filtration, and purification of animal diets. Data on temperature, humidity, light intensity, noise intensity, and on the metal content of air, feed, water, and cage materials were presented.

297 Knapp, R. M., and Isokrari, O. F., 1976, Aspects of numerical simulation of future performance of geopressured geothermal reservoirs, in Podio, A.L., ed., Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 3, Reservoir research and technology: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 103-161.

Differential equations describing momentum and energy conservation in geopressured geothermal reservoirs are developed. Effects considered in the development of these equations include heterogeneous and anisotropic porous media, water influx from adjacent compacting shales and clays, and reservoir rock compaction as a result of reservoir fluid withdrawal. The equations describe the behavior of the water and gas phases in the reservoir fluids and the behavior of the rock matrix. Constitutive equations describing the effects of pore pressure changes on reservoir parameters are also presented. The equations can serve as the basis for development of computer models of the geopressured geothermal reservoirs.

A model simulating momentum conservation of the water phase in geopressured reservoirs is described.

298 Knudson, K., and Belaire, C. E., 1975, Causes and probable correctives for oxygen depletion fish kills in the Dickinson Bayou estuary, a field study and simplified algal assay: Contr. Mar. Sci. Univ. Texas, v. 19, p. 37-48.

Frequent oxygen depletion fish kills, caused by dense algal blooms, have occured during summers in a portion of Dickinson Bayou directly upstream from two sewage treatment plants. These plants are the major contributors of wastes to the bayou. During summer periods of low freshwater inflow, the treatment plant effluents are carried upstream by tidal action, causing dense algal blooms; algal density is much less above tidal influence and downstream from plant outfalls. Algal assays demonstrated that if the plants employed chemical coagulation to remove phosphorus, the summer algal densities in the critical portion of the bayou would be reduced to concentrations corresponding to, or less than, the levels found in the rest of the bayou. Such treatment would thereby reduce the probability of summer fish kills.

299 Krause, F. R., 1976, Ecosystems impact assessment of geopressured energy development: A program plan. Prepared for the U. S. Fish and Wildlife Service, Coastal Ecosystems Center, 13 p.

Compares the environmental impact of offshore versus inshore development of geopressured energy. Proposes the following ecological assessment of potential geopressured energy development:

1)Determine the impact of onshore geopressured energy development on loss of recreational and public lands. (marsh and estuarine resources),

2)Determine the ecological impact of offshore geopressured development associated with disposal of drilling muds, uptake of cooling waters and ocean diffusion of spent fluids.

3) Recommend optimum combination of onshore and offshore sites that minimize ecological impact of geopressured fluid withdrawal.

4)Accelerate geopressured energy development by coordinating use of study results in ongoing assessment of onshore, secondary stimulation of oil and gas reservoirs, offshore oil and gas leases and construction of nuclear power plants.

300 Kreitler, C. W., 1976, Fault control of subsidence, Houston-Galveston area, Texas: Univ. Texas, Austin, Bur. Econ. Geology Research Note 5, 17 p.

Land subsidence increases the area in the Texas Coastal Zone which will be inundated by marine waters from hurricane flooding. Storm surge from a Carla-sized hurricane in 1976 would flood at least 25 square miles more land than Hurricane Carla did in 1961.

Land subsidence in Harris and Galveston Counties results primarily from ground-water production. The two-county area is interlaced with active surface faults with topographic escarpments and surface faults with no topographic escarpments that control drainage patterns and create subtle photographic linear patterns. Ground-water production activates these faults by differential compaction of the aquifer. The faults appear to be partial hydrologic barriers that compartmentalize land subsidence into several individual basins.

Some useful figures 1) active surface faults and surface traces of extrapolated subsurface faults in Harris and Galveston Counties, Texas, followed by maps showing subsidence in the same areas, 2) and figures depicting fault control of subsidence and of the elevation of the piezometric surface in certain areas.

301 Kreitler, C. W., 1976, Lineations and faults in the Texas Coastal Zone: Univer. Texas, Austin, Bur. Econ. Geology Rept. Inv. 85, 32 p.

Over 7,000 miles of lineations have been observed on aerial photographic mosaics of the Texas Coastal Zone. These lineations, in part, represent the surface traces of faults originating in the Tertiary sediments and propagating through the Quaternary sediments. The extrapolation of subsurface faults from specific oil and gas reservoirs are commonly coincident to lineations in these areas.

In the Houston/Galveston area of land subsidence, lineations commonly correspond with zones of active faulting. Many lineations coincide with zones of differential subsidence; fifty percent of intersections of subsidence profiles and lineations occur at points of differential subsidence. Differential subsidence may be a precursor to active faulting; the land surface flexes before fault displacement is evident. With increased regional subsidence, active surface faults may be expected to develop within zones of differential subsidence.

Movement on faults in the Houston area is being activated and accelerated by ground-water withdrawal. Land subsidence and fault activation can be expected in areas of the Texas Coastal Zone other than the Houston/Galveston area if in these areas there is extensive ground-water withdrawal from shallow, (less than 3,000 ft.) fresh-water artesian aquifers.

Figures include distribution of lineations in the Texas Coastal Zone, and lineations and surface traces of faults extrapolated from the Frio Formation from Matagorda Bay to the Neches River, Texas.

302 Krenkel, P. A., and Parker, F. L., 1969, Biological aspects of thermal pollution: in Proceedings of the National Symposium on Thermal Pollution, Sponsored by the Federal Water Pollution Control Administration and Vanderbilt University, Oregon, 3-5 June 1968, Vanderbilt University Press, 407 p.

Paper presented include discussion and question-answer sections and the topics were as follows: engineering aspects, sources, and magnitudes of thermal pollution; remarks on the effects of heated discharges on marine zooplankton; aspects of the potential effect of thermal alteration on marine and estuarine benthos; developing thermal requirements for freshwater fishes; some effects of temperature on freshwater algae; the effects of heated discharges on freshwater benthos; theoretical considerations on the effects of heated effluents on marine fishes; effects of heated discharges on anadromous fishes; effects of heated discharges on freshwater fishes in Britain; and research needs for thermal pollution control.

303 Kubicek, P. F., and Price, D. G., 1976, An evaluation of water temperature and its effect on juvenile Steelhead Trout in geothermally active areas of Big Sulphur Creek: Final report to Pacific Gas and Electric Company, Department of Engineering Research, no. 7784.4-75, 43 p.

A water temperature study designed to evaluate the suitability of the habitat for juvenile Steelhead Trout in geothermally active areas of Big Sulphur Creek. Portions of the Creek are classified as lethal, marginal, or satisfactory based on temperature measurements and the literature available on temperature effects on trout. Sections of the stream reach lethal temperatures during the summer due to natural geothermal activity and reduced flow. Low Steelhead populations have been observed in these areas.

304 Kumar, M. B., 1977, Geothermal and geopressure patterns of Bayou Carlin--Lake Sand area, south Louisiana: Implications: Am. Assoc. Petroleum Geologists Bull., v. 61, p. 65-78.

The Bayou Carlin-Lake Sand area is part of a well-known "hot belt" and geopressured region of south Louisiana. The area is characterized by a rim syncline (with Cote Blanche salt dome) on the northwest, a gulfward-dipping growth fault on the south, and productive structures of Lake Sand, East Lake Sand, and Bayou Carlin fields. The mapping of the geopressured zone shows that its roof shallows over the structural highs and the downthrown side of the growth fault, and that the geopressure roof has thermal halos over the structural highs. The geothermal mapping of structural horizons in the hydropressured and geopressured zones indicates that the isothermal contours approximate the subsurface structures. The geoisotherms (depth contours) of the 250°F (121°C) datum and isotherms (temperature contours) at four depth levels (10,000; 12,000; 14,000; and 16,000 ft. or 3,048; 3,658; 4,267; 4,877 m) suggest that the structural highs are associated with thermal highs, and that the rim synclinal zone of the Cote Blanche salt dome is hot because of a greater heat flow from the salt diapir.

For the study area, graphs showing mud density(formation pressure) and temperature versus depth are plotted. In addition the following maps are given: (1) maps of the structure and temperature at the top of the geopressured zone; (2) isothermal contour maps of two structural horizons--the upper horizon is within the hydropressured zone and the lower horizon is within the geopressured zone; (3) geo-isothermal contour maps of three temperature datums: 200, 250, 300°F, (4) isothermal contour maps at 10,000, 12,000, 14,000, and 16,000 ft. of depth.

305 Kunin, R., 1973, A macroreticular boron-specific-ion-exchange resin: in Kothny, ed., Trace Elements in the Environment, Advances in Chemistry Series, Amer. Chem. Soc., no. 123, p. 139-143.

Recent laboratory studies and field operations have demonstrated the excellent performance of a macroreticular boron-specific-ion-exchange resin, Amberlite XE-243, for deborating several process streams, sea water, and irrigation water. One large plant is now operating successfully on sea water. Further studies on this product are currently in progress in several areas throughout the world.

306 Kunze, J. F., Miller, L. G., and Whitbeck, J. F., 1975, Moderate temperature utilization project (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-21.

The volume of geothermal waters and the energy utilizable per temperature increment undoubtedly increases rapidly with decreasing temperature. Despite the theoretical attractiveness of moderate temperature (100° to 150°C) reservoirs, the commercial technology for economically generating electricity from such waters does not exist today. A research project to develop more economical methods of utilizing such resources has been undertaken by the Energy Research and Development Agency. The Raft River Valley in Southern Idaho, typical of the Basin and Range Valley situation in the U. S., was selected; extensive geophysical work followed and deep exploratory drilling commenced in early 1975.

Design of a power conversion system has examined both multiple flash steam cycles and a variety of binary fluid systems, both boiling cycles and supercritical cycles. Power output vary from 6 to 11 watts per kg/hr of geothermal fluid. Selected cycles have received detailed conceptual design sufficient to obtain a cost estimate. Low initial temperatures (150°C) require transfer of large quantities of fluid to the plant and to reinjection sites. Thus reservoir management for long-life is a major technical aspect of such a power plant. Results show a double flash steam system is more economical than a binary system, at least in modules of 100 MW or less with fluid at 150°C. Development of more efficient and less costly heat exchangers such as fluidized bed and direct contact, immiscible fluid devices is in progress. If developed, the binary system would become more attractive vis-a-vis steam. Results to date show that the fluidized bed system effectively inhibits scale formation.

307 Kutepov, L. Ye., and Dodolina, V. T., 1970, Effect of irrigation with effluents from the Volga chemical combine on the agromeliorative characteristics of light chestnut loam soils (vliyaniye orosheniya stochnymi vodami volzhskogo khimkombinata na agromeliorativnyye pokazateli tyazhelosuglinistykh svetlokashtanoyykh pochy): Pochvovedeniye, no. 7, July, p. 84-93.

The problem of using mineralized waste water to irrigate solonetzic light chestnut clay loam soils is examined in connection with the hazards of salinization and solonetzization resulting from the composition and degree of mineralization of the water. Light chestnut clay loam soils became desalinized and desolonetzized after 3 years of irrigation with effluents from the Volga chemical combine. These effluents have a mineralization of 11 to 18 mg/liter and a sodium content of 8 to 13 mg/liter. The irrigation rate must be at least 2000 mm of water to prevent the top horizons from becoming salinized as a result of the uptake of salts from the nearby salt horizon (80 to 90 cm). A formula employed by the U. S. Department of Agriculture for evaluating the ratio and content of cations in irrigation water is recommended as being most consistent with the law of ion-exchange reactions. Although the content of hydrolyzable nitrogen decreased in light chestnut clay loam soils after three years of irrigation, it remained fairly high. The potassium content increased in most cases during the irrigation period, constituting 39 to 92 mg/100 g of soil. This is considered a very high value for calcareous and chernozemic solonetzes. The P_2O_5 content decreased sharply (from 8.0-10.0 mg. to 1.0 to 1.4 mg/100 g). Irrigation with the total effluents of the Volga chemical combine produced crop yields three to four times higher than those obtained when irrigation was not used, (Josefson-USGS).

308 Kutkuhn, J. H., 1966, The role of estuaries in the development and perpetuation of commercial shrimp resources: in A symposium on estuarine fisheries, Amer. Fish. Soc., Spec. Pub., no. 3, p. 16-36.

This report summarizes knowledge concerning functional relationships between the estuarine environment and commercial shrimp resources. Discussion is largely restricted to North American species; attention is focused upon situations evolving specifically as a result of the rapid urban and industrial development of our estuary-rich Gulf Coast.

The association of shrimp and the brackish-water environment from ontogenetic and ecological points of view is reviewed. The question of continued productivity and perpetuation of shrimp stocks in the face of man's steady incursion of estuaries is considered. Also considered are measures that might be taken to counteract real, or imagined, effects of society's development of coastal wetlands.

309 Lane, R. A., and Macpherson, L. A., 1976, Review of geopressure evaluation from well logs --Louisiana Gulf Coast: Jour. Petroleum Technology, v. 28, September, p. 963-971.
Recent Gulf Coast drilling experience and log data reveal irregularities in resistivity trends. Anomalies caused by age boundaries, younger sediments and other phenomena may make log relationships difficult to apply. The geographic distribution and interpretation techniques for some of these anomalies are presented. Resistivity-trend departure/pressure relationships are examined. To estimate formation pressures from logs in the Gulf Coast, the following information is necessary: (1) an established normal log response trend in hydropressured shales, (2) an observed departure from the normal trend, and (3) an empirical relationship between this trend departure and formation pressure gradient.

310 Lang, E., 1975, Einige rechtliche fragen der raumordnung und der bodenreform im zusammenhang mit dem bau von energievorsorgungsanlagen. (Some legal questions of area planning and agrarian reform arising in connection with the construction of energy supply facilities): Oesterr Z. Elektr., v. 28, p. 449-454.
The existing constitutional and administrative system in Austria gives rise to legal problems relating to area planning schemes and the preservation of the environment. Even though the construction of energy supply facilities may require licenses from several authorities, global consideration of different interests is not ensured. Energy supply facilities often encroach upon agriculture lands or woodlands, and special problems arise due to the public character of the agrarian rights. In German.

311 Lassiter, R. R., 1975, Modeling the dynamics of biological and chemical components of aquatic ecosystems: By the Southeastern Environmental Research Laboratory for the Environmental Protection Agency, 62 p.
To provide capability to model aquatic ecosystems or their sub-systems as needed for particular research goals, a modeling strategy was developed. Submodels of several processes common to aquatic ecosystems were developed or adapted from previously existing ones. Included are submodels for photosynthesis as a function of light and depth, biological growth rates as a function of temperature, dynamic chemical equilibrium, feeding and growth and various types of losses to biological populations. These submodels may be used as models

in the construction of models of subsystems or ecosystems. A preliminary model for the nitrogen cycle subsystem was developed using the modeling strategy and applicable submodels.

312 Lauer, G. J., Waller, W. T., and Lanza, G. R., 1975, Interfaces of steam electric power plants with aquatic ecosystems: Envir. Letters, v. 9, no. 4, p. 405-430.

Growth and reproduction may be stimulated by increased temperature in the cooling system and thermal plume during seasons when ambient temperature is less than optimal, but growth, reproduction and survival are reduced when the elevated temperatures become excessive. Some fish species congregate in the warm themal plumes during cold seasons but are excluded from this living space by temperatures above their preference during the summer. However, the warm refuge provided by a thermal plume in cold seasons can be a death trap if a power plant shuts down suddenly and exposes the fish to cold shock exceeding their lower thermal tolerance limits. Each of these factors tends to affect different segments of the biota.

313 Lauff, G. H., 1967, Estuaries: American Association for the Advancement of Science, Pub. no., 83, 757 p.

A good general text on estuaries covering the following topics as chapter headings: Basic considerations; Physical factors: Geomorphology; Sediments and sedimentation; Microbiota; Nutrients and biological production; Ecology and populations; Physiology and evolution; Fisheries; Human influences; and a Summary.

314 Lawrence Livermore Laboratory, 1977, Geothermal Subsidence research program plan: Univ. California, Berkeley, Lawrence Livermore Labs., Energy and Environment Div., no. LBL-5983 UC-66E TID-4500-R65, 111 p.

This document presents the development of a comprehensive research program to investigate potential subsidence from geothermal energy production. The objective of geothermal subsidence research is to control or initigate potential subsidence associated with geothermal development within predictable limits. In this way, geothermal programs may proceed without delays and siting flexibility may be increased.

The subsidence program will be composed of five major elements: 1) characterization of subsidence, 2) physical theory of subsidence, 3) properties of materials, 4) simulation of subsidence and 5) subsidence control. Each of these elements will be further broken down into categories for which individual research projects will be proposed.

315 Layton, D. W., 1976, Water supply dilemas of geothermal development in the Imperial Valley of California: Lawrence Livermore

Laboratory, a paper prepared for submission to the Twelfth American Water Resources Conference and Symposium, Chicago, Ill., 19-20 September 1976, 21 p.

The relatively high water requirements of geothermal facilities along with a series of real and potential constraints may cause water supply dilemas involving both the acquisition and use of cooling water. This paper examines these constraints and related dilemas in light of relevant information on the Imperial Valley's water resources, geothermal resources and energy technologies, cooling water requirements, and water supply options.

316 Lee, G. F., Lopez, J. M., and Mariani, G. M., 1976, Leaching and bioassay studies on the significance of heavy metals in dredged sediments: Univ. Texas, Dallas, Center for Environmental Studies, preprint, 65 p.

This study examines the release of heavy metals from dredged sediments from various locations in the U. S. These studies have shown that for sediments tested thus far, the only heavy metal released in potentially significant amounts to possibly be adverse to water quality at a dredged material disposal site water column is manganese. Bioassays of the elutriates of dredged sediments were conducted to examine the toxicity of released metals and other contaminants to aquatic organisms. The toxicity of the sediment elutriate mixtures was insufficient to be adverse to aquatic organisms in a typical open water disposal site water column.

This study includes sediments from the Trinity River and Houston Ship Channel, the Galveston, Texas City, Corpus Chrisit, Port Aransas and Port Lavaca in Texas.

317 Lee, G. F., Piwoni, M. D., Lopez, J. M., and others, 1975, Research study for the development of dredged material disposal criteria: Univ. Texas, Dallas, Institute for Environmental Sciences Contract Rept. D-75-4, 381 p.

The elutriate test was designed to evaluate the release of chemical contaminants from hydraulically dredged sediments in disposal site water columns. Sediments used were from the Trinity River, Houston Ship Channel Turning Basin, Port Aransas Channel and Corpus Christi Bay, Texas; Mobile Bay, Alabama, Bridgeport, Connecticut; and Ashtabula, Ohio, Harbor on Lake Erie. The oxygen content of the elutriate was found to be one of the most important factors influencing the release of chemical contaminants from dredged sediments during the elutriate test. Under oxic conditions, only manganese (II) and ammonium were released in potentially significant amounts to the elutriate from the sediments tested. Little or no release of nitrate, organic nitrogen, total phosphorus, orthophosphate, copper, lead, cadmium, iron, or PCB's occurred. Zinc and selected chlorinated hydrocarbon pesticides, such as the DDT group, were removed from the test water for some sediments. The amounts of ammonium and manganese released are potentially sufficient to cause acute lethal toxicity to some forms of aquatic life in the disposal site water column, if conditions of little or no mixing of disposal site water with the water in contact with the dredged sediments occur.

318 Lee, J. J., 1976, Effects of environmental stress on the community structure and productivity of salt marsh epiphytic communities: Progress report, September 1, 1975-August 31, 1976. City College, New York, 200 p. (NTIS:COO-3254-32).

The importance of food quality (strength of food web bonds) was shown in a study of seasonal switching in a harpacticoid copepod. Unlike the evidence obtained for some planktonic species, size of algal food was not an important factor in the feeding of Nitocra typica. The animal has nutritional requirements which seem to adapt it to feed on different species and strains of algae which are likely to occur in the community at different seasons. The results of this study suggest complexions in trophic dynamics which explain some of the diversity inherent in the closely packed niches of micro- and macrofauna in detrital food webs. An in situ incubation subproject aimed at testing the effects of water quality, heavy metals, and crude oil on natural assemblages of diatoms were also completed. Since the experimental communities were confined and recruitment could not take place, changes in the diatom assemblages were due to their biotic interactions within the context of the ambient environmental fluxes. Though the initial populations of transplanted diatom assemblages were quite dissimilar, convergent changes took place in the assemblage trajectories during summer succession. Comparisons of the trajectories of the metallic ion and crude oil enriched assemblages brought out similarities of patterns. The best correlation in succession trajectories was between oil and Pb (approximately 75%). Iron enrichment favored the development of a community quite different from controls or other experimentals. Recurrent group analysis of the diatom flora gave insight into species selected by the experimental conditions.

319 Lehmann, E., 1974, Environment and quality of life. Literature study on the economic consequences of the damages and annoyances both in materials and vegetation and in men and animals caused by sulfur dioxide air pollution: Commission of the European Communities, Luxembourg, 150 p. (NTIS:EUR-5134d)
On account of its frequent occurrence in the atmosphere near the ground and its reactivity, sulfur dioxide (SO_2) is an essential contributor to negative effects of air pollution. Frequently economic damage is caused by SO_2, especially to agricultural crops and to forests. With reference to human health, its effects are principally combined with other air pollutants, especially particulates. The effects upon animals are of no practical or economic importance. The damage of sulphur dioxide upon materials has been proved beyond doubt. The economic consequences of air pollution in general and of SO_2 in particular are discussed only rarely in the relevant European literature. The existing gaps appear to be due to the uncertain nature of the subject as well as to a delay of research. Proposals for corresponding research programs are made. Most studies published on damages caused by air pollution do not refer to individual components, but to air pollution as a whole. The findings and estimates of costs incurred by air pollution have their origin mostly in the USA. Within the EC, comprehensive reports were available only from the UK, France, and Italy, but no one of these reports gives any estimates on the proportion of costs caused by sulphur dioxide alone. Some cost estimates have been made in Sweden on damages caused by SO_2. In German.

320 Lehmann, E. J., 1974, Water quality modeling: A bibliography with abstracts: National Technical Information Service, Springfield, Virginia, no. COM-74-10938/0, 163 p.
The bibliography contains 158 selected abstracts of research reports containing information on models of the chemical, physical, biological, and hydrological processes important to water quality. Included are studies on the modeling of eutrophication, nutrient removal, pollutant dispersion, stream flow, heat dissipation, limnological factors, and storm water runoff.

321 Lehmann, E. J., 1975, Thermal pollution. Part 2. Biological effects (A bibliography with abstracts): National Technical Information Service, Springfield, Virginia, no. PS-75/219/6ST, 176 p.

Presented are 171 abstracts covering the effects of heated effluents on fish, microorganisms, and plants in both fresh and salt water. This includes the effects on growth, ecology, metabolism, heat tolerance, and productivity.

322 Lehmann, E. J., 1976, Ground water pollution, Part 1, General studies (A bibliography of abstracts): National Technical Information Service, Springfield, Virginia, Rept. for 1964-September 1976, 239 p.

Except for studies dealing with irrigation or fertilization, topics include ground water quality, modeling, hydrology, pollution from landfills and injection wells, aquifer pollution, sources, hydrogeology, and pollution abatement planning. (This updated bibliography contains 233 abstracts, 41 of which are new entries to the previous edition.)

323 Leighton, D., Nusbaum, I., and Mulford, S., 1967, Effects of waste discharge from Point Loma saline water conversion plant on intertidal marine life: Jour. Water Pollution Control Fed., v. 39, no. 7, p. 1190-1202.

The purpose of the study was to determine the organisms significantly reduced or absent in the area of the Point Loma saline water conversion plant point of discharge as compared with neighboring areas and therefore the recognizable extent of influence of the effluent within the intertidal zone and those animals among common characteristic intertidal species which are and are not affected by several concentrations of samples from the discharge water in laboratory aquaria.

324 Leitner, P., and others, 1976, Environmental effects of noise from geothermal resource development: Natl. Sci. Found., Geothermal Energy Program Current Research Projs., Grant #75-14178, March, 27 p.

Description of a study being carried on at The Geysers, California, to evaluate whether birds and small mammals actively avoid habitats in which geothermal-related noise is intense, whether physical damage to hearing can result, and whether noise can interfere with vocal communication signals essential for survival or reproduction. Noise emissions from geothermal areas are those that accompany the release of steam or hot water, the operation of mechanical equipment, and the drilling of geothermal wells.

325 Leland, H. V., Copenhaver, E. D., and Corrill, L. S., 1974, Heavy metals and other trace elements: Jour. Water Pollution Control Fed., v. 46, no. 6, p. 1452-1476.

A review of the literature for the year of 1973 on heavy metals and related trace elements. Contains extensive reference section.

326 Leland, H. V., Copenhaver, E. D., and Wilkes, D. J., 1975, Heavy metals and other trace elements: Jour. Water Pollution Control Fed., v. 48, no. 6, p. 1459-1486.

A review of the literature for the year 1975 on heavy metals and related trace elements. Contains extensive reference section.

327 Lengquist, R., 1975, Geothermal steam piping systems at Big Geysers, California, USA (abs): in Second United Nations Symposium on California, 20-29 May 1975, Abstract volume, VI-28.

Successful operation of geothermal steam gathering systems at the Geysers natural steam fields, now spans a period of 15 years. The steam is delivered to steam turbine-generators for 412 MW of electrical power generation. Steam conditions are about 120P/360F (8.44 kg/cm^2/ 185c) when in production. Non-condensables in the steam total 0.2 to 0.5% of the whole with 90 to 95% of the gases being CO_2. Other gases are CH_4, H_2, N, NH_3, H_2S, argon and traces or radon.

The gathering systems are protected from over-pressure by modulating type relief valves backed up by rupture discs pegged at 170P. Internal surfaces are relatively free of corrosion, but show signs of water and dust erosion at turns and restrictions. In-line separators hold these problems to a minimum. Pipe insulating material of 3" fiberglass blanket with an asbestos-aluminum-vinyl cover results in a total heat factor loss of 0.15 btu/sq. ft. /degree F.

Noise abatement dquipment for steam release into the atmosphere is designed for attenuation to 80dBa at 100′ from the source. All types of mufflers are still under evaluation for optimum performance and economics. Pipe materials used are of low carbon steel specification A53 - Grade B the equivalent, using cast steel slab gate valves with stainless steel trim and stems for control of steam flow.

328 Leopold, A. S., Fox, I. K., and Callison, C. H., 1970, Missouri Conservation Program: an appraisal and some suggestions: An Independent Study Funded by the Edward K. Love Conservation Foundation, St. Louis, Missouri.

An excellent presentation of the rationale for more general sources of funding as related to a broadened conception of the public interest.

329 Leopold, L. B., Clarke, F. E., Hanshaw, B. B., and Balsley, J. R., 1971, A procedure for evaluating environmental impact: Geol. Survey Circular, no. 645, 13 p., chart.

This report contains a procedure that may assist in developing uniform environmental impact statements.

330 Lewis, C. R., and Rose, S. C., 1969, A theory relating high temperatures and overpressures: Jour. Petroleum Technology, v. 22, no. 1, p. 11-16.

The theory proposed in this paper is that an overpressured zone, because it is less compacted, constitutes a thermal barrier. That is, this uncompacted zone contains excess amounts of water, and water has three times the insulating value of the rock matrix. This theory is discussed and then compared with field data from two areas, N. E. Thompsonville field in South Texas and offshore Texas in the Galveston area. Practical applications of the theory are considered.

331 Lincer, J. L., Haynes, M. E., and Klein, M. L., 1976, The ecological impact of synthetic organic compounds on estuarine ecosystems: Mote Marine Laboratory, Sarasota, Florida, 364 p.

The review and indexed bibliography concerns the presence and effects of pesticides and industrial toxicants in the estuarine ecosystem. The review covers literature of the last decade, with emphasis on the most recent 5 years. However, the 700+ references in the bibliography span a much wider range. A permuted keyword retrieval system is provided to allow practical use of the bibliography.

332 Lindal, B., 1975, Development of industry based on geothermal energy, geothermal brine and seawater in the Reykjanes Peninsula in Iceland (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, IX-5.

Development work regarding the Sea-Chemicals Complex, invisaged in the Reykjanes Peninsula in Iceland, is continuing. During 1970 to 1974, a drillhole of 1700 m was kept discharging steam and brine freely to the atmosphere in the Reykjanes area. The change in flow rate proved to be moderate, and there was no change in chemical composition of the original fluid. A small pilot plant for the concentration of the brine was operated in 1971. These experiments indicated that no pretreatment of the brine was necessary. Further, that it would be most suitable to separate the silica from the brine after concentration to saturation in respect to sodium chloride. An acceptable level of heat transfer was obtained in forced circulation evaporators. As a preparatory step regarding the final design of a 250,000 ton salt plant, a major pilot plant operation is being planned for 1975-76.

During 1970-72, extensive experimental work was conducted regarding the production of magnesium chloride as related to production of metallic magnesium. The basic raw materials considered were seawater and geothermal salt. Soda ash would be a by-product. Two processes were tested for the conversion of magnesium bicarbonate and salt into magnesium chloride and soda ash. Both appear to be technically and economically feasible, assuming the use of geothermal steam. Some considerations have also been given to other areas in the Sea-Chemicals Complex, such as caustic soda and chlorine. All process design and development is focused on the use of geothermal energy, wherever this is useful.

333 Littleton Research and Engineering Corporation, 1970, An engineering-economic study of cooling pond performance: Littleton Research and Eng. Corporation, EPA Proj. #16130 DFX 05/70, Contract #14-12-521, 141 p.
An analytical procedure for predicting the steady state and transient temperatures of condenser cooling water obtained from a cooling pond is presented. The predictions require knowledge of monthly average climatic and power plant operating parameters. Measured water temperatures for several operating cooling ponds distributed over the United States are compared to values predicted on the assumption of fully mixed ponds and slug flow ponds.

Economic analysis of the use of captive cooling ponds is also given.

It is shown from these analyses that it is possible to obtain cooling water temperatures in a captive cooling pond which are within 5°F of the equilibrium temperature of a natural water supply with a pond area of approximately 4 acres per megawatt. The water requirements for a properly designated pond are not greatly different from those of a cooling tower. Where areas of adequate size are available and not too expensive, the use of a cooling pond can result in lower overall electrical costs than cooling towers and be reasonably competitive with those of a natural water supply. Cooling ponds can provide a positive contribution to the recreational, aesthetic and ecological values of a community.

Includes data collected on operating cooling ponds in Jefferson, Texas and Shreveport, Louisiana for analysis and comparison.

334 Loftin, L. L., and Agnew, L. B., 1967, Soil survey interpretations for engineering works and land development, Terrebonne Parish, Louisiana, U. S. Dept. Agriculture, Soil Conserv. Service, 16 p.
This supplement used in coordination with the Soil Survey of Terrebonne Parish gives information on which sound land use planning can be based. Information includes estimated engineering properties of the soils of the Parish, interpretation of soils for urban, recreational and road construction uses, and suitability of soils as a source of construction material.

335 Loftin, L. L., and Agnew, L. B., 1969, Soil interpretations, St. Mary Parish, Louisiana, First supplement to the Soil Survey of St.

Mary Parish, Series 1953, No. 3: U. S. Dept. Agriculture, Soil Conserv. Service, 17 p.
The purpose of this supplement is to add estimated engineering properties and selected land use interpretations to the St. Mary Parish Soil Survey issued in March, 1959. Information includes estimated physical and chemical properties and suitability of soils for selected uses such as urban and recreational, earthwork and foundation engineering, and as construction material.

336 Loftin, L. L., and Sonmier, I., 1962, Soil interpretations, Acadia Parish, Louisiana: U. S. Dept. Agriculture, Soil Conserv. Service, Series 1962, no. 15, 33 p.
This supplement provides more engineering and soil interpretation data for several land uses, and is to be used with the published soils survey of Acadia Parish. Some of the land uses for which soil ratings are given are septic tank absorption fields, sewage lagoons, sanitary landfills, building and road construction, and recreational uses.

337 Loosanoff, V. L., 1961, Effects of turbidity on some larval and adult bivalves: Proceedings of the Gulf and Caribbean Fisheries Institute, 14th Session, p. 80-95.
The article is devoted to an analysis of experiments on the effects of turbidity upon larval and adult bivalves. Studies of Crassostrea virginica and Venus mercenaria are emphasized although several other species are also considered. Different species of mollusks, their eggs and larvae were affected to different degrees by the same concentrations of the same turbidity-creating substances. Data indicated that lamellibranchs feed most effectively in relatively clear water.

338 Lorensen, L. E., 1975. Polymeric and composite materials for use in systems utilizing hot, flowing geothermal brine (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-29.
To assist development of the Lawrence Livermore Laboratory "Total Flow" concept for the utilization of hot geothermal brine to produce electrical power, a materials selection program has been started. Piping, turbine nozzles and blades, and condenser systems will be needed. A program in Critical Path Method format including laboratory and field testing has been outlined. Polymers and composites resistant to the high temperatures, corrosive brine and erosive conditions present in a flowing well are being sought and tested. Results from inhouse long term tests in 300°C brine show that certain polymers, i.e. those containing either substantial aromaticity, fluorine, carbonized structure, or aliphatic unsaturation which has been crosslinked, show considerable stability. The presence of water sensitive groups such as

imide, amide, or ester is detrimental even in very thermally stable polymers. In field tests with a flowing well, a fluorocarbon polymer exhibits promising resistance to both erosion and scale deposition, which is very important in high solids content brine.

339 Louisiana Air Control Commission, 1974, Air control regulations, State of Louisiana: Louisiana Air Control Comm., Louisiana Health and Human Resources Adm., Div. Health, August 1, 67 p.
A statement of the regulations, policies and guidelines enforced by the Louisiana Air Control Commission. Detailed information and tables listing the standards of ambient air quality and emissions is given.

340 Louisiana Department of Conservation, 1970, Summary of field statistics and drilling operations, Louisiana: Louisiana Dept. Conserv., Louisiana Geol. Survey, 133 p.
Included are: a) a list of abbreviations, b) District and State Summary of drilling operations for 1970, c) a list of 29 discoveries that were named in 1970, of which 26 were actually discovered in 1970, d) field statistics by Conservation Districts and Offshore, e) cumulative offshore drilling operations from 1938 thru 1970, f) salt water disposal report, g) miscellaneous well report, h) waste disposal well data.

341 Louisiana Department of Conservation, 1971, Summary of field statistics and drilling operations, Louisiana: Louisiana Dept. Conserv., Louisiana Geol. Survey, 124 p.
Included are a) lists of abbreviations used, b) District and State Summary for 1971 and a comparison from 1966 through 1971, c) a list of the 23 discoveries that were named in 1971 of which 19 were actually discovered in 1971, d) field statistics by Conservation Districts and Offshore, e) cumulative offshore drilling operations (excluding zone 4) from 1938 through 1970, f) salt water disposal and disposition report, g) miscellaneous well report, and h) waste disposal well data.

342 Louisiana Department of Conservation, 1972. Summary of field statistics and drilling operations, Louisiana: Louisiana Dept. Conserv., Geol. Oil and Gas Div., 112 p.
Included are a) lists of abbreviations used, b) District and State Summary for 1972 and a State Summary Comparison from 1967 through 1972, c) a list of the 25 discoveries that were named in 1972, d) field statistics by Conservation Districts and Offshore, e) cumulative offshore drilling operations (excluding zone 4) from 1938 through 1970, f) salt water disposal and disposition report, g) miscellaneous well report, and h) waste disposal well data.

343 Louisiana Department of Conservation, 1973, Summary of field statistics and drilling operations, Louisiana: Louisiana Dept. Conserv.,

Geol. Oil and Gas Div., 106 p.
Included are a) lists of abbreviations used, b) District and State Summary for 1973 and a State Summary Comparison from 1968 through 1973, c) a list of the 18 discoveries that were named in 1973, d) Field Statistics by Conservation Districts and Offshore, e) salt water disposal and disposition report, f) miscellaneous well report and g) waste disposal well data.

344 Louisiana Department of Conservation, 1974, Summary of field statistics and drilling operations, Louisiana: Louisiana Dept. Conserv., Geol. Oil and Gas Div., 112 p.
Included are a) lists of abbreviations used, b) District and State summary for 1974 and a State Summary Comparison from 1969 through 1974, c) a list of the 42 discoveries that were named in 1974, d) Field Statistics by Conservation Districts and Offshore, e) salt water disposal and disposal report, and f) a miscellaneous well report.

345 Louisiana Geological Survey, 1974, Underground salt water and waste disposal in Louisiana State regulations and geological concepts: Louisiana Dept. Conserv. Pub., June, 23 p.
These are Louisiana's rules and regulations pertaining to underground salt water and industrial waste disposal, along with the approval procedure for each type of disposal well. Schematic diagrams of typical salt water and industrial waste disposal wells are included, along with a geological cross-section of the Baton Rouge area. A table lists Louisiana's 77 permitted industrial waste disposal wells.

Part 1 pertains to salt water disposal regulations. Title 30, Chapter 1, Section 4, para. C of the Louisiana Revised Statutes of 1950 gives the Louisiana Dept. of Conservation the authority to protect fresh water sands from contamination by oil, gas, or salt water.

Statewide Order 29-B governs the drilling, production, and plugging of oil and gas wells in Louisiana, and the amendment to Statewide Order 29-B which is dated October 19, 1967 further regulates the disposal of salt water into surface bodies or hydrocarbon producing formations. It may be disposed of in approved pits or tidally affected brackish waters not fit for human consumption or agricultural purposes.

Another amendment to Statewide Order 29-B dated February 27, 1974, is Sec. XIX F-3 c and d, which concerns abandonment procedures. The procedure for obtaining a salt water disposal permit is given.

Part 2 contains the procedure for permitting an industrial waste disposal well. The authority of the Louisiana State Board of Health to regulate the disposal of sewage and other waste material is granted in the Sanitary Code for the State of Louisiana, and provides for the protection of fresh water in a number of provisions listed in this part.

Part 3 illustrates geological factors essential for the proper handling of both salt water and industrial waste disposal.

346 Louisiana Water Resources Division, 1976, Water resource data for Louisiana, water year 1976: Volume 2, Southern Louisiana. Geol. Survey Pub., nos. USGS/WRD/HD-76/055 & USGS/WDR/LA-76-2, 837 p.

Water resources data for the 1976 water year for Louisiana consist of records of stage, discharge, and water quality of streams; water quality of lakes; and water levels and water quality of wells. Records are also included for a few pertinent stations in bordering states. These data represent part of the National Water Data System operated by the U. S. Geological Survey and cooperating State and Federal agencies in Louisiana.

347 Louisiana Wetlands Prospectus, 1973, Report of the Louisiana Advisory Commission on Coastal and Marine Resources, 346 p.

This report addresses two questions. What are the needs and problems that Louisiana faces in the use of its coastal and marine resources now and in the future? What actions should state government take to insure the orderly, long-range conservation and development of Louisiana's coastal and marine resources?

348 Louisiana Wildlife and Fisheries Commission, 1971, Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Phase I, Area description and Phase IV, Biology: 175 p.

Phase I covers the geology and dimensions of the estuarine study areas. Includes vegetation distribution, stream discharge, public and private oyster leases and population statistics for the area. Considers commercial fisheries installations, domestic and industrial wastes, filled and drainage areas and channelization.

Phase IV considers six coastal study areas as to fishes and invertebrates collected in trawl and seine samples systematically; and discusses the commercial fishery. Correlations are made of catches to salinity and temperature. There is a section concerned with the analysis and treatment of zooplankton captured in the bay systems. Includes a systematic list of zooplankton, and treats the species with regard to temperature, salinity, and relative abundance within the study areas. There is also a discussion of the seasonal distribution of organisms with regard to temperature and salinity. Contains an extensive bibliography.

349 Louisiana Wildlife and Fisheries Commission, 1976, Environmental conditions relative to shrimp production in coastal Louisiana: Tech. Bull., no. 21, 20 p.

Shrimp catch data are presented along with environmental factors which influence the shrimp harvest. Environmental data for the first four months of 1976, particularly in the Barataria-Caminada Bay area, are compared with previous years. Relationships between shrimp harvest and river discharge, rainfall, salinity, water temperatures and the available amount of nursery area are presented.

350 Louisiana Wildlife and Fisheries Commission, 1976, An inventory and study of the Lake Ponchartrain-Lake Maurepas estuarine complex: Tech. Bull., no. 19, 159 p.

An investigation of the composition, general distribution, and abundance of commercially or potentially important fauna inhabiting the estuarine complex area for comparison with previously reported data. Vertebrate and invertebrate populations were sampled, including molluscs and zooplankton. Hydrological and climatological data were collected to coincide with the faunal samples.

351 Ludviksson, V., 1975, Multiple uses of geothermal energy. Electric power generation and horticultural production (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume IX-6.

Heating of greenhouses already presents an important use of geothermal energy in Iceland. The heat usually is supplied in the form of hot water at about 100°C. Greenhouse industries at northern latitudes have commonly used the equivalent of 100 kg per square meter in a year to provide the necessary heat to maintain production. At far northern latitudes, light becomes a limiting factor in winter production of horticultural products.

The steam from high temperature thermal fields can be used to produce electricity while the residual heat from flashed geothermal water and possibly any condensation can be used to provide artificial lighting of plants. An economic evaluation based on 33.5 hectares of glass houses and 14 MW steam power plant shows that the cost of heat to the greenhouse complex would be about 2% of the total operating cost, while the same energy from an oil or other hydrocarbon source would result in about 35-40% of the operating cost at correspondingly higher total operating cost.

The effectiveness of artificial lighting in maintaining or promoting plant production is a major unknown factor, which greatly depends both on the type of light source, its arrangement and the type of plant species to be produced. Research is being initiated on this subject in Iceland.

352 Ludviksson, V., 1975, Drying of seaweed with geothermal heat (abs.): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume IX-7.

Developing new uses for the widely occurring low-temperature fluids (temperatures below 130°C) is one of the most challenging and economically interesting tasks in resource development in Iceland. Presently a plant is being erected for the drying of some 6800 tons yearly of common rockweed (Ascophyllum nodosum) in western Iceland. The product of seaweed meal is intended as a raw material for the alginate industry. The project will most likely lead to large scale uses of geothermal heat for the drying of grass for animal fodder in Iceland in the coming years, using similar technology.

The five tier belt dryer is adapted from a German vegetable and hops dryer and the technique is suitable for all drying processes where heat sensitive products such as vegetables or pharmaceutical plants are to be machine dried. The penalty of the higher investment cost of the belt dryer as opposed to the rotary dryer systems is more than offset by the lower operating cost and energy reliability of the geothermal heat. The investment for plant and harvesting machinery is estimated at 2.88 million dollars, while yearly product value is about 1.6 million dollars.

353 Lund, J. W., Culver, G. G., and Svanevik, L. S., 1975, Utilization of intermediate temperature geothermal water in Klamath Falls, Oregon (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VIII-12.

Klamath Falls, Oregon, is located on a known geothermal resource area which has been used by residents, principally in the form of hot water for space heating, at least since the turn of the century. Approximately 400 shallow depth wells ranging from 27 to 580 meters (90 to 1900 feet) in depth are used to heat approximately 500 structures. This utilization includes the heating of residences, schools, businesses (including a creamery for milk pasturization), heating swimming pools and melting snow from pavements.

Well water, which ranges from 38°C (100°F) to 100°C (230°F), has been used directly in heating and drinking water systems, however, present practice is to use down-hole, hair-pin, heat exchangers with city water as the circulating fluid. Well water chemistry indicates approximately 800 mg/1 (ppm) dissolved solid, with sodium and sulfate having the highest concentrations. Calcium and potassium concentrations are very low. Some scaling and corrosion does occur on the downhole heat exchangers (black-iron pipe) which is related to the Langlier Saturation Index.

Cost analysis for capital and annual operation costs are presented and compared with alternate forms of energy (electricity, natural gas and fuel oil). For a single residence, at today's costs, heating using geothermal water appears to be somewhat competitive; however, when several structures use the same well, the savings are substantial. District heating, similar to that in operation in Iceland, is proposed.

The average annual energy utilization is only 5.6 megawatts with peak use at 56 megawatts. It is felt that only a small portion of the area's potential is being utilized, with the potential of steam at great depth.

354 Lytle, S. A., 1971, The Soils of Terrebonne Parish, Louisiana: Louisiana State University, Dept. Agronomy, Agr. Expt. Sta. Bull. no. 651, 112 p.

The continuing industrial expansion and the increasing demand for food, fiber, and oil crops have resulted in an increasing demand for more detailed information about the soils of the coastal parishes of Louisiana, and how these soils may be best utilized. Also, there has been an increasing interest in the use-potential of the wetlands--the coastal marshlands and swamps of the coastal parishes.

The purpose of this report is to present physical, chemical, and mineralogical data on the soils of Terrebonne Parish which may serve as a basis for making predictions about the behavior of the soils when they are used for farming, engineering, or other purposes. The detailed data are essential for making interpretations about the usefulness of the soils and for determining the proper kinds of management necessary for the most efficient uses of the soils.

The data included in this report are the result of a study of soil samples from 79 sites in Terrebonne Parish. The information presented is supplemental to that of the soil survey report of Terrebonne Parish which was published in 1960 as a cooperative project of the Louisiana Agricultural Experiment Station and the USDA, Soil Conservation Service.

355 Lytle, S. A., Grafton, B. F., Ritchie, A., and Hill, H. L., 1959, Soil survey, St. Mary Parish, Louisiana: U. S. Dept. Agriculture, Soil Conserv. Service, Series 1952, no. 3, 45 p., maps.

The St. Mary Parish Soil Survey contains a soil association map and air photo coverage of the parish with soil types delineated. Six soil associations are designated, and the soil series within these associates are described. Other soil information includes use, management, and factors of soil formation. Introductory sections describe physiography, relief, climate, and water supply and give historical information about population and land usage.

356 Lytle, S. A., McMichael, C. W., Green, T. W. and Francis, E. L., 1960, Soil survey, Terrebonne Parish, Louisiana: U. S. Dept. Agriculture, Soil Conserv. Service, Louisiana Agr. Expt. Sta., Series 1956, no. 1, 43 p., maps.

The Soil Survey of Terrebonne Parish contains a soil association map and air photo coverage of the area with soil types delineated. A description of soils grouped by capability units, use and management, genesis, morphology, and classification is also given. The introductory section includes information on physiography, climate, relief, drainage, and agricultural statistics. Chemical analyses of representative soil and from the coastal marshes and of water taken from these soils are listed in tables.

357 Lytle, S. A., and Sturgis, M. B., 1962, General soil areas and associated soil series groups of Louisiana: Louisiana State Univ. and Agr. and Mech. Coll., Dept. Agronomy, Agr. Expt. Sta., map.
General map of soil areas and associated soil series in the State of Louisiana, and a description of each soil association.

358 Mackin, J. G., 1961, Canal dredging and silting in Louisiana bays: Pub. Inst. Mar. Sci. Univ. Texas, v. 7, p. 262 - 314.
Effects of dredging on oysters were studied in shallow bays of Louisiana and discussed relative to the normally high turbidities of an eroding marsh. Data were taken from unpublished reports of projects of the Texas A&M Research Foundation.

359 Mackin, J. G., 1971, A study of the effects of oilfield brine effluents on biotic communities in Texas estuaries: Texas A&M Research Foundation Project, no. 735, 72 p., figures and tables.
Study attempts to measure the effects of brine effluents on the marine communities of Texas bays as produced in association with oil and gas. Areas of study included: Trinity Bay, Upper Trinity Bay, Clear Lake, Clear Creek, Menefee Lakes, Lavaca Bay, Matagorda Bay, and Baffin Bay. Each site is discussed in terms of: numbers of species and individuals present, taxon diversity, reproductive capacity, sensitive groups and species, and their capacity to colonize sheltered areas and test plates.

360 Mackin, J. G., and Hopkins, S. H., 1961, Studies on oyster mortality in relation to natural environments and to oil fields in Louisiana: Pub. Inst. Mar. Sci., Univ. Texas, v. 7, p. 1-131.
Field and laboratory studies and examination of historical records were made in the tidal waters of Louisiana to determine the possible role of operations of oil companies on mortality of commercial oysters, Crassostrea virginica. It was concluded that oil production factors of the kinds tested could not be responsible for the oyster mortalities spread throughout the large area where damage was claimed. The widespread mortalities that did occur during the study period were correlated with high temperature and high salinity, but not with proximity to oil operations.

361 Marsh, S. E., 1975, Evaluation of NOAA satellite data for geothermal reconnaissance studies (abs): in Second United Nations Symposium for the Development and Use of Geothermal Resources, San

Francisco, California, 20-29 May 1975, Abstract volume, III-60. Research concerning the applicability of the NOAA Very High Resolution Radiometer (VHRR) to geothermal studies is in progress. The VHRR sensor is sensitive to energy in the visible spectrum at 0.6 - 0.7 µm and in the thermal infrared at 10.5 - 12.5 µm, with twice daily coverage of the continental United States (at approximately 0900 and 2100 hrs local time), and with a ground spatial resolution of approximately one km. The NOAA satellite contains a blackbody reference source, thereby permitting the calculation of calibrated "surface" temperatures.

A reading- and analysis-program for digitized nine-track tape records from the NOAA satellite was written at the Stanford Remote Sensing Laboratory for the PDP-10 computer. The approximate scale of the computer output is 1:225,000, resulting in improved evaluation capabilities from the normal VHRR image scale of approximately 1:7,500,000. The interactive program can produce raw satellite data (numerics), histograms of the data, and shadeprints in which appropriate intervals (gray scale steps) may be stretched or enhanced in order to optimize the result for a particular application.

The geothermal areas of Yellowstone National Park, Wyoming, are under study, because the aerial size of a number of the geothermal areas provides compatible resolution with the VHRR sensor. A preliminary analysis of the computer-derived images of the park indicated delineation of some geothermal areas is possible. This initial research indicates that the NOAA thermal sensor system can already provide a data source for some geothermal reconnaissance studies.

362 Marshall, N., Skauen, D. M., and Oviatt, C. A., 1970, Sensitivity of benthic microflora to pollution gradients: Rhode Island University, Kingston, R. I., 70 p. (NTIS:PB-192 853).

The objective of this research was to evaluate relationships between the productive condition of the sediment environment and pollution effects normally experienced along a densely populated coastline. Specifically the work was designed to: improve the methodology for measuring the productivity of the benthic microflora community;determine the normal rate of productivity of the microflora community of shoal benthic environments, as indicated by the rate of C^{14} uptake by intact samples of samples; compare this norm with productivity in an area affected by heavy domestic pollution and an area affected by thermal addition.

363 Martinez, A. R., 1972, Coastal hydrographic and meteorological study. Coastal Fisheries Project Report, 1972, Texas Parks and Wildlife Department, p. 146-197.

Latest in a yearly series of reports of hydrological and meteorological data for Galveston, Matagorda, Aransas, Corpus Christi, Upper and Lower Laguna Madre Bay areas. These reports date back to 1960-1961 and included additional information on unusual occurrences such as droughts and hurricanes.

364 Maslan, F., Gordon, T. J., and Stover, J., 1975, Technology forecast of U. S. geothermal energy resource development, in Second United Nations Symposium on the Development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, p. 2049-2420.

This forecast defines the nature of the technology on which this industry depends, the technological impediments which, if uncorrected, might block its growth, the means available to overcome the impediments, and the range of energy production levels which might possibly be expected from this source. A complete geothermal energy technology relevance tree was first constructed, and was followed by designed interviews with industrial and scientific authorities. The results of these two steps were analyzed in a series of energy system diagrams synthesizing the overall judgments about technologically feasible levels of development, unconstrained by economic and institutional considerations. The accelerated case U. S. geothermal electricity capacity predictions for 1985 are: vapor, 3500; liquid, 17,000; hot dry rock, 5000; geopressured, 10,000 Mwe. For the year 2000, the predictions are: vapor, 10,000; liquid, 500,000; hot dry rock, 200,000; geopressured, 54,000 Mwe.

After this analysis, an electric utility simulation model of the decision mechanism involved in the choice and construction of new central station generating capacity was developed. In effect, this system dynamics model simulated the introduction of geothermal energy into the U. S. utility marked. The model incorporated economics, construction time, reliability, fuel availability, environmental factors, and technology. These forecasts simulate the real geothermal energy electricity capacity development, and for 1985 are: normal development, 7000 Mwe; accelerated development, 19,500 Mwe. The predictions for the year 2000 are: normal development, 188,000 Mwe; accelerated development, 249,000 Mwe.

365 Mason, D. V., 1969, Houston-Galveston air pollution emission inventory: Durham, North Carolina, Natl. Air Pollution Control Adm., Rept. #APTD-0818, 62 p.

A summary is presented of the emission inventory of the Houston-Galveston metropolitan area. The report provides estimates of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide, and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, and geographical distribution within the area. The study area consisted of eight counties surrounding the cities of Houston and Galveston.

366 Mather, J. R., Swaye, F. J., and Hartmann, B. J., 1973, The influence of the climatic water balance on conditions in the estuarine environment: Delaware University, Newark. College of Marine Studies, 105 p. (NTIS:COM-73-11326/8).

This publication consists of two studies. The first is concerned with estuarine response to factors of the climatic water. In this study it was found that it is possible to determine net flow at the mouth of a body of water such as an estuary by means of evaluating all the input and withdrawal terms in the hydrologic equation. Quantitative values of the monthly outflow at the mouth of the estuary were provided. The importance of the relative contribution of runoff from various areas of the basin, of precipitation and of evaporation to the overall water flow in the estuary was suggested. It was shown that the water balance of the area plays a significant role in the quality of water of importance to shellfish and man. The second study examined the effect of urbanization on annual water yield in a particular watershed. It was found that urbanization increased the annual water yield in this watershed.

367 Mathis, D. B., and Cobb, S. P., 1976, An investigation of the environmental impacts associated with the disposal of dredged material at the offshore disposal site, Galveston, Texas (abs): in Proceedings of the Eighth Dredging Seminar: College Station, Texas A&M Univ., Center for Marine Resources, Sea Grant Rept. TAMU-SG-77-102, Center for Dredging Studies, CDS Rept. 195, p. 179-180.

The Environmental Effects Laboratory (EEL) of the Waterways Experiment Stations (WES), in conjunction with the Galveston District, Corps of Engineers, has established a field research study at the offshore dredged material disposal site near Galveston, Texas. This site is one of four regional study sites established by the EEL for the purpose of evaluating the environmental impacts associated with the open water disposal of dredged material. In order to effectively evaluate these impacts in terms of cause and effect relationships, a comprehensive research effort is being undertaken at the site and at adjacent areas to the site in order to define natural and unnatural changes in the sediments and water column, and the associated flora and fauna of each. Particular emphasis is being placed on determining the significance of certain physical, chemical and biological factors that govern the rate and extent by which dredged material disposal sites are colonized by benthic organisms.

This paper describes contracted physical, chemical, and biological research undertaken at the study site during the Phase I investigations and discusses the experimental design formulated for the Phase II investigations, utilizing controlled disposal techniques. The paper will also present a recent history of dredged material disposal activities by the Corps of Engineers within the northern Gulf of Mexico, as well as an overview of planned research to be undertaken at the site by EEL.

368 Matthew, P., 1975, Geothermal operating experience at Geysers power plant (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-22.
Fourteen years operating experience at Pacific Gas and Electric Company's Geysers Power Plant have demonstrated that geothermal electric power generation can be reliable and economical. Location, terrain, environment, personnel considerations and operating requirements created new and unique problems compared to traditional thermal power generating practices. Common interests and goals of the steam supplier and the power plant operator have helped in their solution. Much has been learned about the selection of equipment and materials.

369 Maugh, T. H., 1976, Natural gas: United States has it if the price is right: Science, v. 191, p. 4227.
Evidence was presented at a meeting of the National Research Council forum on potential resources of natural gas that, if gas companies were allowed to sell new gas at prices comparable to those already charged for intrastate deliveries, they might be able to tap already-identified sources that would greatly increase natural gas reserves. This price would remain competitive with the prices of alternative energy supplies. Four types of natural gas resources that are presently unexploited are examined, these are gas trapped in coal deposits, gas from shales, gas from tight sands, and gas from geopressured zones. The U. S. has natural gas resources of about 8 trillion cubic meters that can be produced and sold at current prices, with an additional 18.5 trillion cubic meters of undiscovered natural gas in conventional deposits.

370 May, R. C., 1976, Effects of Salton Sea water on the eggs and larvae of Bairdiella icistia (Pisces: Sciaenidae): California Fish and Game, v. 62, no. 2, p. 119-131.
In laboratory experiments, eggs and larvae of the sciaenid fish Bairiella icistia survived well in sea water but displayed extremely poor survival in water from the Salton Sea. Mortality in Salton Sea water was expressed mainly among hatched larvae prior to complete yolk absorption. Experiments conducted in both natural and artificial sea water and Salton Sea water indicated that this poor survival was related to the unusual ionic composition of the Salton Sea.

371 McCabe, B. C., 1975, Practical aspects of a viable geothermal energy program (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-23.

Magma Power Company, which has now drilled more than 200 geothermal wells, pioneered today's U.S. geothermal operations by successfully completing a dry steam well at The Geysers in 1955. After drilling in many other areas, Magma concluded that all additional U.S. fields probably would involve hot brine; consequently it was essential to develop a binary cycle process of generation. Patents for such a process, named by Magma "The Magmamax Power Process", were obtained by it in 1973. Magma's experience established that resources and technology are now available so that geothermal energy can make an earlier and more significant contribution to the U.S. goal of international energy independence than any other prospect. Unfortunately, bureaucratic obstacles have unreasonably escalated costs and caused delays running into years.

Magma proposes the following program to expedite production of electricity from geothermal sources: (1) Erection and operation of at least one 10 MW and one 50 MW binary cycle plant (Magma is currently engineering such plants for construction), (2) simplified government regulations and environmental controls both in one agency, accompanied by favorable tax treatment, (3) prompt issuance of leases on Federal lands in accord with the Congressional intent contained in the Leasing Act of 1970, and immediate implementation of the loan guarantee provisions contained in the Geothermal Energy Act of 1974, and (4) concentration of field efforts on drilling, pumping and testing to prove the existence of viable fields, and of research on binary cycle plant operation problems, all without illogical duplication. Acceleration of any program requires the cooperation, heretofore lacking, between this industry, government, and utility companies.

372 McConnell, J. C., McElroy, M. B., and Wofsy, S. C., 1971, Natural sources of atmospheric CO: Nature, v. 233, September 17, p. 187-188.

Methane is produced at the earth's surface by various biological processes. Substantial methane is produced in rice paddies and coastal marshes.

Reactions of the hydroxyl ion with methane or the oxidation of methane in the troposphere leads to permanent destruction of CH_4 and subsequent formation of CO and CO_2.

373 McDowell, G., 1975, The scrubbing of chlorides in carry over water from geothermal well separators (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-32.

With the advent of two-phase (steam-water) transmission from a wet geothermal bore field to the power station, the problem of chloride removal from the steam prior to turbine inlets has arisen. Theoretical calculation on the scrubbing performance of steam within pipelines from the steam separators has been done, and practical tests carried out on Wairakei bore field steam lines have achieved similar results.

The dryness of steam from separators used in the Wairekei field averages at 99.95% while chloride content of the carry over water is 1500 PPM. Extensive tests show that the steam is scrubbed in the pipeline through normal condensation and cleared through drain pots. The drains at Wairakei are poorly designed and improperly placed in regard to the flow patterns within the pipeline; despite these defects the chlorides are reduced to below 2 ppm within 400 m of the separators. Condensation pots and drains of improved design together with the placement of such drain units at points on the pipelines where flow patterns are regular could reduce the scrubbing length considerably.

374 McGhee, E. D., 1959, Surface mud system: Oil and Gas Jour., v. 57, October, p. 107-122.

This article describes a complete mud system at the surface; pits, tanks, mud screens and de-sanders, mud agitators and mixers, centrifugal concentrators, degassers and other mud instruments, and mud storage and handling.

375 McGinnis, J. T., Ewing, R. A., Willingham, C. A., Rogers, S. E., Douglass, D. H., and Morrison, D. L., 1972, Final report on environmental aspects of gas pipeline operations in the Louisiana coastal marshes: Columbus, Ohio, Battelle, Columbus Labs., 120 p.

This paper presents composite environmental data involving installment and operation of gas pipelines in the coastal marshes of Louisiana. Coastal marshes are delineated from the low water line by the Gulf of Mexico to high ground some 20 to 40 miles inland. Objectives of the study are: (a) developing and documenting the existing knowledge on the environmental effects of gas pipeline operations in the marshlands, (b) identifying the gaps in existing data required to predict the consequences of additional pipeline operations and defining programs to fill the data gaps, (c) formulating general conclusions based upon the present state of knowledge of the impacts of developments following the offshore lease sales. Data include dredging operations, marsh ecosystems description, ecological, socioeconomic, and cultural effects.

376 McGowen, J. H., Brown, L. F., Jr., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, Environmental geologic atlas of the Texas Coastal Zone--Bay City-Freeport area: Univ. Texas, Austin, Bur. Econ., Geology, 98 p., maps.

The Environmental Atlas of the Texas Coastal Zone is designed to provide an urgently needed inventory for this most vital area of Texas. Presented is information on the nature of the Coastal Zone, what is happening to it, and at what rate changes are taking place. The basic environmental geology map delineates and depicts in detail resource units of first-order environmental significance. The accompanying series of eight special-use maps is designed for particular information needs. Included are physical properties and land use suitability, current land and submerged land topographic and bathymetric configuration, natural and artificial water systems, and climate. Statistical tables define and inventory the more than 250 natural and cultural features of the Texas Coastal Zone. A descriptive text explains the data presented, their utility, and means of extrapolating the data for other special uses.

This volume contains an inventory of natural systems and natural resources in an area along the Texas Gulf Coast including parts of Brazoria, Calhoun, Fort Bend, Jackson, Matagorda, and Wharton Counties.

377 McGowen, J. H., Proctor, C. V., Jr., Brown, L. F., Jr., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, Environmental geologic atlas of the Texas Coastal Zone--Port Lavaca area: Univ. Texas, Austin, Bur. Econ. Geology, 107 p., maps.

The Environmental Atlas of the Texas Coastal Zone is designed to provide an urgently needed inventory for this most vital area of Texas. Presented is information on the nature of the Coastal Zone, what is happening to it, and at what rate changes are taking place. The basic environmental geology map delineates and depicts in detail resource units of first-order environmental significance. The accompanying series of eight special-use maps is designed for particular information needs. Included are physical properties and land use suitability, current land use, active physical processes, mineral and energy resources, land and submerged land topographic and bathymetric configuration, natural and artificial water systems, and climate. Statistical tables define and inventory the more than 250 natural and cultural features of the Texas Coastal Zone. A descriptive text explains the data presented, their utility, and means of extrapolating the data for other special uses.

Included in the map area of this volume are parts of Aransas, Bee, Calhoun, Goliad, Jackson, Matagorda, Refugio, and Victoria Counties, Texas.

378 McHugh, J. L., 1966, Management of estuarine fisheries: *in* A Symposium on Estuarine Fisheries, Ninth Annual Meeting, American Fisheries Society Special Pub., no. 3, p. 133-153.

Addresses the problem of lack of understanding of the estuarine ecosystem as an integral part of the life cycle of the greatest portion of the species that are basically considered to be offshore fisheries resources. Solution to this and associated problems will require improved public understanding, increased support and coordination of research and management programs, and greater opportunity for calm discussion and compromise.

379 McKenzie, W. F., Truesdell, A. H., 1975, Geothermal reservoir temperatures estimated from the oxygen isotope composition of dissolved sulfate and water from hot springs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, III-65.

O^{18}/O^{16} and D/H ratios of waters and O^{18}/O^{16} ratios of dissolved sulfates from hot springs were determined in six major geothermal systems in Yellowstone National Park, Wyoming (U.S.A.) δO^{18} (H_2O) varied with chloride content, but δO^{18} (SO_4) was nearly constant $(-12 \pm 1\,^{\circ}/_{\circ\circ}$ relative to SMOW) for most waters studied. Steam-loss and mixing models were used to estimate the O^{18}/O^{16} ratio of the deep reservoir water for each system. The residence time of dissolved sulfate in the deep reservoir is sufficient to ensure isotopic equilibrium between dissolved sulfate and water, and waters ascent to the surface rapidly relative to the rate of isotopic exchange. Except for waters containing sulfate of surficial origin, calculated temperatures of last sulfate-water isotopic equilibrium ranged from 320 to 420°C for all geothermal areas within the Yellowstone caldera. These temperatures are higher than those indicated by other geothermometric methods.

380 McLaughlin, R. J., 1975, Pre-Tertiary geology and structural control of geothermal resources, the Geysers steam field, California (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, II-30.

In The Geysers steam field of northern California, Upper Jurassic and Cretaceous rocks of the Franciscan assemblage form the core of a south-eastward-plunging antiform that has been highly modified by late Tertiary and Quaternary faulting. These intensely deformed volcanic and sedimentary rocks are metamorphosed to pumpellyite and lawsonite grade and exhibit textural reconstitution that generally increases in the direction of the structurally highest rocks. Comparison of the structure of these Franciscan rocks with micro-earthquake and resistivity data suggests that economically significant steam reservoirs are in part related to local fault-controlled structural traps. In an area of shallow stream production near The Geysers Resort, the epicenters and foci of numerous microearthquakes and extensive hydrothermal alteration are associated with a zone of N 30° - 35° W - trending faults that dip steeply to the northeast. The microearthquakes and hydrothermal alteration may be related to hot water or steam-saturated rock in the fault zone. Structural control of steam resources is also indicated near

Castle Rock Spring, approximately 4 miles southeast of The Geysers Resort. A low resistivity anomaly over the Castle Rock Spring stream field is probably due to rock saturated with hot water. This presumed zone of water-saturated rock lies between steeply dipping faults trending N 80° W and is overlain by foliate metagraywacke, basaltic volcanic rocks, and serpentinite. Steeply dipping faults trending N 50° W may bound the east side of the Castle Rock Spring steam reservoir.

381 McLean, D. D., 1969, Subsurface disposal--Precautionary measures: Indus. Waste Eng., August, p. 20-22.
This is a general description of possible hazards of subsurface injection of liquid wastes and precautionary methods to be considered (not specifically salt water disposal).

382 McMillan, C., 1974, Salt tolerance of mangroves and submerged aquatic plants: *in* Reimold and Queen, eds., Ecology of Halophytes, Academic Press, N. Y., p. 379-390.
Mangroves and submerged aquatic plants, the seagrasses, share a niche attribute of tolerance to broad and rapid changes in salinity. Includes discussion of the degree of tolerance of various species of these plants and how stage of development affects this tolerance.

383 McMillan, C., and Moseley, F. N., 1967, Salinity tolerance of five marine spermatophytes of Redfish Bay, Texas: Ecology, v. 48, no. 3, p. 503-506.
Thalassia testudinum, *Halophila engelmanni*, *Diplanthera wrightii*, *Ruppia maritima*, and *Syringodium filiforme* are the major plants of the highly productive estuaries along the Texas coast. Salinity tolerance tests indicated that *Diplanthera* was the most tolerant. Lesser salinity tolerance was found in *Thalassia* and *Ruppia*, while *Syringodium* was least tolerant of high salinity. *Halophila* survived sporadically, but showed active growth at high salinities. Distribution of the plants indicates that there is at least a partial correlation with their salinity tolerances.

384 McWilliams, J., 1971, Large saltwater-disposal systems at East Texas and Hastings oil fields, Texas, *in* Cook, T. D., ed., Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoir 18, Symposium Proc., Houston, Texas, December 6-9, p. 331-340.
The disposal of salt water produced with oil from the East Texas field has been successful in minimizing pollution of land areas and freshwater sources, and has also been effective in maintaining bottomhole pressure. To date, 4.5 billion bbl of salt water has been returned to the producing reservoirs at a cost to the operators of approximately 2.5¢/bbl.

At Hastings field, in Brazoria and Galveston Counties, Texas, Amoco is successfully disposing of 50,000-60,000 bbl/day of salt water by injection into saltwater-bearing formations below freshwater-bearing sandstones and above the oil-producing zones. The project is a "closed system", whereby the salt water produced is allowed no contact with air; therefore, corrosion attack on disposal facilities is reduced. To date, Amoco has injected approximately 500 million bbl of salt water.

385 Messinger, H., 1963, Dissipation of heat from a thermally loaded stream: U. S. Geol. Survey Prof. Paper 475-C, p. C175-C178.
This is a comparison of measured down stream temperatures from a heated section of the West Branch of the Susquehanna River below the Shawville power plant with predicted energy-budget method values. The actual rate of cooling of the stream was considerably greater than that predicted by theory. Discrepancies between predicted and actual downstream temperatures are attributed mainly to inadequacies in existing methods for measuring the effective solar and atmospheric radiation of partially shaded water surfaces.

386 Meyer, C. F., 1973, Polluted groundwater: Some causes, effects, controls and monitoring: Santa Barbara, California, General Electric Company, and Las Vegas, Nevada, TEMPO Environmental Monitoring and Support Lab., Contract #EPA-68-01-0759, 283 p.
Groundwater pollution aspects of the following topics are discussed: institutional and legal constraints; injection wells into saline and freshwater aquifers; lagoons, basins, and pits; septic systems; sewer leakage; spraying; land fills; surface-groundwater relationships; saltwater intrusion; land subsidence and collapse; effects of urbanization and flow diversion, including wells and surface structures; spills of liquid pollutants; tank and pipeline leakage; and groundwater basin management, including related surface activities.

387 Minohara, Y., 1975, The geothermal utilization in the Atagawa tropical garden and alligator farm (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume IX-8.
This paper includes the outline of the use of geothermal energy for cultivating of plants and breeding of animals in the Atagawa Tropical Garden and Alligator Farm, Atagawa, one of the famous hot springs near Tokyo.

At present, 450 crocodilians (alligator, crocodile, cayman, gavial) of 27 kinds are bred, and artificial incubation of them has succeeded by utilizing hot water and steam from 4 hot spring wells. Crocodilians are breeding in the various ponds in water at temperatures of 20-28°C. Water and bodily temperature are measured by an infrared thermometer.

While in the hothouse, also by utilizing hot spring heat, more than 5,400 kinds of tropical plants, orchids and ornamental plants are grown, especially 63 kinds of tropical water lilies growing in hothouse with regulated air and water temperature.

Annual visitors reach 800,000.

388 Minucci, G., 1975, Heat extraction from hot water geothermal fields (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-33.

A study is made of a hot water geothermal field containing gas and considerable amounts of different qualities of mineral salts dissolved in solution.

In traditional mineral exploitation where the water is brought to the surface by wells, scaling occurs on the inside of the pipes and equipment especially during exploitation by flashing.

Exploitation of such a field, without the above serious inconveniences, can be achieved by drilling special wells which act as heat exchangers within the terrains containing the reservoir. Heat is extracted by this type of well by means of conduction through the casing, utilizing an intermediate fluid which enters at the wellhead and returns to the surface through a well-insulated tubing.

The heat is utilized on the outside of the well either through an exchanger or directly in recovery equipment in which the intermediate fluid is circulating in a closed cycle. The amount of heat extracted in time units is less than that obtained by direct exploitation of the water, but the total amount which can be extracted remains the same. Exploitation can be improved by putting two or more nearby wells in series.

Circulation of the intermediate fluid is similar to that of a central heating plant, where the geothermal field represents the boiler providing the heat.

389 Moffett, A. W., 1975, The hydrography and macro-biota of the Chocolate Bayou estuary, Brazoria County, Texas (1969-1971): Texas Parks and Wildlife Department Tech. Series, no. 14, p. 1-72.

Analysis of the seasonal abundance of animals and the hydrology of the Chocolate Bayou estuary, a small body of water adjoining West Galveston Bay, were based on data collected between May 1969 and October 1971. Includes a partial, annotated list of the macro-biota. It was found that White and Brown Shrimp were the dominant large crustaceans and the Bay Anchovy the principal fish.

390 Moore, D., Brusher, H. A., and Trent, L., 1970, Relative abundance, seasonal distribution, and species composition of dimersal fishes

off Louisiana and Texas, 1962-1964: Mar. Sci., v. 15, p. 45-70. Dimersal fishes were collected monthly with a shrimp trawl at 33 to 60 stations in 7 to 110 m (4-60 fathoms) between the Mississippi River Delta and the U.S.-Mexico border from 1962-64. Comparisons were made between Texas and Louisiana catches at various depths, seasons, and day-night differences.

391 Moore, W. R., 1969, A contribution to the biology of the Blue Crab (Callinectes sapidus Rathbun) in Texas, with a description of the fishery: Texas Parks and Wildlife Department Technical Series, no. 1, p. 1-31.
Research on the biology of the Blue Crab was begun in Texas in 1962 by TP&WD biologists. Information on seasonal abundance, growth, movements and environmental relationships from these studies was used to study trends in crab populations, while a survey of the fishery provided information on the size of the catch and market conditions. Catch data were treated as to fishing effort, catch per unit effort, and seasonal catch fluctuation. Peak spawning periods were determined as well as recruitment rates. Distributions of crabs by size, season and sexual maturity were related to temperature and salinity. Also includes information from crab tagging tests.

392 Moreland, J. B., and Minto, R. F., 1976, Example of in-plant noise reduction with an acoustical barrier: Appl. Acoust., v. 9, p. 205-214.
Existing theories for predicting the distribution of sound intensity in rooms and the performance of acoustical barriers are applied in designing a barrier to reduce noise in an industrial environment. The combination of the theories is found to predict the sound pressure level in the barrier shadow zone reasonably well.

393 Morse, W. F., Lofstrom, J. R., and Smith, W. H., 1968, A study of process energy requirements in the food industries: Am. Gas Assoc., Inc., Indus. Sales Promotion Comm., Cat. #C-20008, 87 p.
This is a survey of the various food industries and their energy uses and requirements. For each industry studied a summary of its growth and technological advancements are given and the industries' characteristics are described. Total energy requirements and types of energy used for different processes are given as well as location of the companies and plants. Useful tables give information on gas consumption, regional distribution of production, and the amount of energy supplied by different fuels. The industries studied include: meat, dairy, canned and frozen foods, grain mills, bakery products, sugars and confectionary products, beverages, fats, oils and miscellaneous foods.

394 Moseley, F. N., 1975, Environmental considerations and economic implications in the development of geothermal energy, in Dorfman, M. H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal energy conference: Univ. Texas, Austin, Center for Energy Studies, p. 321-324.

Discussion of environmental concerns and economic feasibility in the development of geopressured areas.

Man's activities produce an impact on the environment, and in developing a new resource, this impact should be minimized. However, the resource and its development should be economically competitive with current resources and processes. A solution would be to develop a number of ways to predict the environmental or ecosystem response to man's activities, so that rational judgements can be made as to the best operational criteria for minimizing this impact. Major impacts such as disposal of spent geothermal water and subsidence should be given prime consideration.

395 Moseley, F. N., and Copeland, B. J., 1974, Brine pollution system in coastal ecological systems of the United States: in Odum, H. T., Copeland, B. J., and McMahan, E. A., eds., Coastal Ecological Systems of the United States, Volume 3, The Conservation Foundation, Washington, D. C., p. 342-352.

From desalization plants and oil field operations come large quantities of highly concentrated salt water. Not only is the salt in high concentrations, but the ratio of salts is quite different from that of sea water. The energetics of the receiving systems are modified with resulting changes in circulation systems, osmotic regulation, stratification, destruction of bottom communities and soil structure, specific heat, hydrogen ion balance, buffer system modification, low species diversity, solubility of oxygen, turbidity and ion balance.

From studies concerning salinas, natural hypersaline lagoons and the cases of brine polluted communities, a picture is developing about the new emerging systems characteristic of brine pollution. Very few organisms are capable of adapting to the high salinities, strange chemical balance and varying inputs of brine waters.

396 Muffler, L. J. P., 1973, Geothermal resource, in Brobst, D. A., and Pratt, W. P., eds., United States mineral resources: U. S. Geol. Survey Prof. Paper 820, p. 251-261.

The geothermal resource base is defined as all the heat about 15°C in the earth's crust, but only a small part of this resource base can properly be considered as a resource. The magnitude of the geothermal resource depends on the evaluation of many physical, technological, economic, environmental, and governmental factors.

Utilization of a greater proportion of the geothermal resource base depends on achieving one or more of the following objectives:

1. Technological advances that would allow electrical generation from low-temperature reservoirs.
2. Breakthroughs in drilling technology that would permit low-cost drilling of holes to depths greater than 3 km.
3. Development of techniques of artificial stimulation that would increase the productivity of geothermal reservoirs.
4. Expansion of the use of low-grade geothermal resources for such purposes as space heating, product processing, agriculture and desalination.

397 Muffler, L. J. P., 1975, Tectonic and hydrologic control of the nature and distribution of geothermal resources (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, II-33.

Under forseeable economics and technology, extraction of geothermal resources from the earth is limited to the upper few kilometers. At these depths, the distribution of geothermal resources on a global scale is controlled by tectonic features. Magma, hot dry rock, and convective hydrothermal systems tend to be concentrated along plate tectonic features (spreading ridges, zones of convergence, inter-arc basins and hot spots). Broad areas of high heat flow and sporadic thermal springs can be related to fossil plate-tectonic features. Young tectonic basins such as the Gulf of Mexico have low near-surface heat flow, but high rates of sedimentation and subsidence combine with contemporaneous faulting to produce geopressured reservoirs at depth. The continental nuclei have low heat flow, display little volcanism or tectonism, and accordingly have relatively low geothermal potential except at depths beyond present drilling limits.

The hydrologic properties of crustal rocks are very important in determining location, size and type of geothermal resource. Hot dry rock can result from solidification of a young intrusive body or from conductive heating of impermeable rock around such a body. Convective hydrothermal systems result either from convection of meteoric water around young silicic intrusive bodies or from deep circulation of meteoric water along fracture zones. Geopressured reservoirs are formed in deep sedimentary basins when escape of connate water and water produced by the thermal dehydration of clays is impeded by sediments of low permeability.

398 Narasimhan, T. N., and Witherspoon, P. A., 1975, Development of a numerical model for land subsidence in geothermal systems (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975.

The possibility of land subsidence in areas where liquid-dominated geothermal systems are being exploited is a problem that merits attention, especially from the standpoint of the environmental impact.

Presented here is the development of numerical methods of handling nonisothermal fluid flow, and of isothermal fluid flow in deformable geologic systems. The present work is an attempt to combine these two methods and thus develop an ability to study subsidence in geothermal systems. The numerical model is an integrated finite difference scheme which solves the fluid-heat flow equations in general three dimensions, but uses the one-dimensional consolidation theory for stress-strain relationships. Results of some hypothetical field situations are presented to demonstrate the applicability of this numerical approach to subsidence.

399 National Academy of Sciences, 1976, Natural gas from unconventional geologic sources: Washington, D. C., Natl. Research Council, Board on Mineral Resources, ERDA contract #E(49-18)-2271.

There are four major types of occurrences of large amounts of methane that have not been exploited to any significant degree. These are (1) in the deep geopressurized zone of the Gulf Coast, (2) in association with the brown shales of the Appalachian and other eastern Devonian-Mississippian basins, (3) in tight sands of the Uinta, Peceance, and other western basins; and (4) in association with coal. In a series of thirteen written papers presented in a forum sponsored by the Board on Mineral Resources and in discussions following the presentation of the papers, evaluations were made of the nature and physical dimensions of these beds, the extent of the resource, recovery problems, economic and institutional problems, and the potential of the source both in the short-term and the long-term. The papers and discussions are compiled together with a summary of the findings and conclusions.

400 National Commission on Water Quality, 1972, Water Pollution Control Act of 1972, Regional impacts: Houston Ship Channel/Galveston Bay, Vol. 1, Final report: Houston, Texas, Johnson (Bernard) Inc., contract #WQ5A059, 922 p.

The environmental, social, economic, and institutional impacts of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) on the Houston Ship Channel and Galveston Bay are reviewed. The study area includes Harris, Galveston, Chambers, and parts of Brazoria counties. Three levels of abatement, BPT (best practicable control technology), BAT (best available technology) and EOD (elimination of the discharge of pollutants) are reviewed. Growth in population, number of households, number of jobs, and available labor force will be enhanced by the 1977 (BPT) and the 1983 (BAT) standards of the law. Authors suggest withdrawal of the 1985 EOD goal in light of its high cost and marginal effect on the social, ecological, and economic fabric of the study area.

401 National Field Investigation Center, 1971, Report on pollution affecting shellfish harvesting in Galveston Bay, Texas, 298 p. (NTIS:PB-213 751/0).

The report summarizes presently available information pertaining to the quality of the Galveston Bay system in Texas; evaluates the information with respect to applicable standards, statutes, regulations, and criteria; and recommends a program which will lead to compliance with established water quality uses. Specific objectives are included: describing existing water quality; identifying sources of pollution; evaluating impact of present waste discharges on water quality and uses; and indicating the effects of projected water related development upon water quality.

402 National Lead Corporation, 1966, What's new with mud?: Nat. Lead Corporation, Baroid Div., Spec. Rept., 35 p.

This updates previous work on drilling developments and techniques, including improvements in drilling rates, use of new mud techniques, hole stability techniques, solids control, and downhole mud temperature stability and corrosion. Illustrated with new experimental studies.

403 National Marine Fisheries Service, 1976, An environmental survey of effects of dredging and spoil disposal, New London, Conn: Middle Atlantic Coastal Fisheries Center informal report, no. 16, 80 p.

Analysis of benthic macrofauna populations continued to reveal no distinct impact of spoiling outside the immediate disposal area. Impacts of dredging on overall concentrations of suspended materials were small. Concentrations of heavy metals in tissues of oysters, hard clams and another bivalve showed significant differences both among species and with time for a given species. The data indicate that the species concentrate metals differentially, but that the temporal changes were independent of dredging.

404 National Research Council, 1977, Copper: Committee on Medical and Biological Effects of Environmental Pollutants: Environmental Protection Agency Publication, no. EPA/600/1-77/003, 194 p.

The report is a review of current knowledge of the distribution of copper in the environment and living things. Metabolism and the effects of copper in the biosphere are also considered. Copper compounds are common and widely distributed in nature. They are also extensively mined, processed and redistributed by man. Copper is an essential element in plant and animal nutrition. It is closely related to iron, sulfur, and molybdenum in animal metabolism. Requirements differ in relation to the nutritional state of these other elements. In plants, copper toxicity is infrequent and usually results from soil contamination due to human activities. Deficiency in plants is fairly common and may require supplementation for crops. In animals both deficiency and toxicity are infrequent except in ruminants. Human copper poisoning occurs rarely in industry, as a cause of food poisoning, resulting from some medical treatments, and from genetic defects in metabolism. Copper levels found in food, water and air have not been found to be injurious.

405 National Water Quality Laboratory, 1975, Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians, 68 p., (NTIS:PB-242 105/5ST).

Four detailed methods for conducting acute toxicity tests with freshwater, estuarine, and marine fish, macroinvertebrates, and amphibians are presented in an integrated format. Nomenclature is consistent with that used in other branches of toxicology. Concepts incorporated into the methods are applicable to toxicity tests with most aquatic organisms.

406 Neff, J. M., Cox, B. A., Dixit, D., and Anderson, J. W., 1976, Accumulation and release of petroleum-derived aromatic hydrocarbons by four species of marine animals: Mar. Biol., v. 38, no. 3, p. 279-289.

When exposed to oil-contaminated seawater, marine animals accumulate a wide variety of petroleum hydrocarbons in their tissues. Generally, the aromatic hydrocarbons are accumulated to a greater extent and are retained longer than the alkanes. In all species tested, accumulation of aromatic hydrocarbons appears to be dependent primarily on a partitioning of the hydrocarbons between the exposure water and the tissue lipids.

407 Nelson, P. M., and Godfrey, N., 1974, Predicting road traffic noise in the rural environment: A study of the A66 road improvement scheme in the lake district: Transportation and Road Res. Lab. (GB), Reprinted, LR, v. 642, 24 p.

Traffic noise measurements have been made alongside 26 miles of the A66 within the Lake District National Park and in the towns of Keswick and Cockermouth in the United Kingdom. The measurements in the towns form the first part of a before and after survey, ultimately to assess the noise benefits to be derived from by-passes which are due to be completed in 1975. The measurements made along the rural sections have been used to derive and validate a noise prediction model appropriate to both the conditions found alongside the A66 and for rural areas generally.

408 Neprimerof, N. N., 1975, Thermal waters as a source of water-flooding of oil reservoirs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco,

California, 20-29 May 1975, Abstract volume, IX-9.
The bulk of oil fields in the USSR utilize secondary recovery methods. Intracontour water-flooding of nonuniform productive horizons with cold surface water causes cooling of the strata and reduction of their productivity. In the Romashkinskoe field in the Tartar ASSR, the losses are 10%. On the contrary, analysis of the working methods and exploration techniques of the October field in the Checheno-Ingush ASSR, which was naturally water-flooded by high temperature waters, shows a productivity increase of tens of percent.

Wide-spread in all oil fields, water-bearing horizons of heated waters and brines can be used as a source of thermal water for flooding of oil reservoirs and as a means of raising their productivity.

409 Netzeband, F. F., Early, J. R., Ryan, J. P., and Miller, W. C., 1964, Sulfur resources and production in Texas, Louisiana, Missouri, Oklahoma, Arkansas, Kansas and Mississippi and markets for the sulfur: U. S. Bur. Mines Inf. Circ. 8222, 77 p.
This is a very comprehensive paper on sulfur production in the seven states, including mining processes, location of reserves, and location of markets (market data and other economic data may be outdated).

410 Odum, H. T., 1963, Productivity measurements in Texas Turtle Grass and the effects of dredging an intracoastal channel: Pub. Inst. Mar. Sci. Univ. Texas, v. 9, p. 48-58.

This investigation involves a comparative study of pre- and post-dredging effects on Thalassia testudinum and Diplanthera wrightii in Redfish Bay near Aransas Pass, Texas. Also considers shading by turbid dredge waters and areas that have been smothered with silt.

411 Odum, H. T., 1967, Biological circuits and the marine systems of Texas: in Olsen and Burgess, eds., Pollution and Marine Ecology, John Wiley and Sons, N. Y., p. 99-157.

A good general description of the marine ecosystem of the Texas coast with a historical review and a look at the effects of industrial man on these systems. Contains an extensive reference section.

412 Odum, W. E., 1970, Insidious alteration of the estuarine environment: Trans. Amer. Fish. Soc., v. 99, no. 4, p. 836-847.

Discusses the estuary as a nutrient trap, a pollution trap, estuarine food webs, the importance of organic detritus, other sources of primary productivity, interruption of energy flow, food chain simplicity, and interference with energy input. Considers the vulnerability of the estuarine organism from the standpoint of sub-lethal effects of pollutants. Sedimentation is discussed in terms of the hydraulic dredge cycle, lowered dissolved oxygen content, dredging and filling, the edge effect and bulk-heading. The importance of freshwater input is covered with reference to the salinity gradient transport mechnaism and estuaries as a source of dissolved organic "roadmaps".

413 Odum, W. E. and Heald, E. J., 1972, Trophic analysis of an estuarine community: Bull. Mar. Sci., v. 22, no. 3, p. 671-738.

A study was conducted between 1967 and 1969 in the North River basin of the Florida mangrove region to determine energy basis for the area's large population of animals and to delineate the routes by which energy is transferred through the food web. This is the first of three publications summarizing the results of this study.

414 Office of Water Resources Research, 1973, Estuarine pollution, A bibliography. Water Resources Scientific Information Center, National Technical Information Service Pub., no. PB-220 119/2, 510 p.

The bibliography contains 324 abstracts and references taken from the Selected Water Resources Abstracts data base of some 50,000 abstracts through December, 1972. The report contains an author index and extensive subject indexes.

415 Office of Water Supply, 1976, Draft environmental impact statement:

State Underground Injection Control Program: Environmental Protection Agency, Proposed Regulations, 40 CFR Part 146, 353 p.

This is an impact statement for the State Underground Injection Control Program, consisting of the proposed regulations 40 CFR Part 146. This document was prepared by the EPA to explain the background of the proposed action and the rationale that was used in developing the regulations. It discusses in detail the anticipated benefits that will result from implementation of the regulations and compares them with adverse impacts that cannot be avoided. Qualitative analysis are made of the effects on various associated factors (e.g. on waters, recreation, Federal agencies). Issues and alternatives are considered in the development of the UIC regulations.

416 Omernik, J. M., 1976, The influence of land use on nutrient stream levels: Environmental Protection Agency Ecological Research Series report, no. EPA-600/3-76-014, 105 p.

Data is concerned with the measurement of drainage area, land use identification, percent land use, animal unit densities, and geological identifications. Results are considered in terms of areal distribution of data, land use-nutrient runoff relationships with category definitions, general analysis and regionality.

417 Orr, F. M., Jr., 1971, Metropolitan Houston-Galveston intrastate air quality control region: Rockville, Maryland, Environmental Protection Agency, Air Pollution Control Office, Air Pollution Rept. #APTD-0998, Federal Facilities, 29 p.

The status of the Federally owned facilities within the metropolitan Houston-Galveston, Texas Air Quality Control Region is presented, with regard to the implementation of the objectives prescribed by the Clean Air Act, as amended. Fuel usage, refuse disposal practices, air pollution emissions, and proposed abatement measures for the listed installations are reported. This region was subsequently redesignated and its boundaries expanded. As a result, the data do not reflect Federal facility emissions data for the additional counties.

418 Oseid, D. M. and Smith, L. L., Jr., 1974, Factors influencing acute toxicity estimates of hydrogen sulfide to freshwater invertebrates: Water Research, v. 8, no. 10, p. 739-746.

Acute bioassay tests of hydrogen sulfide were run on several species of freshwater invertebrates. Size and type of test chamber, type of substrate for burrowing forms or those seeking shelter in gravel, oxygen concentration, pH, and season of collection influenced the sensitivity of organisms. Data indicate that test conditions should approximate natural habitat conditions as closely as practical.

419 Palmer, T.D., 1975, Characteristics of geothermal wells located in the Salton Sea geothermal field. Imperial Valley, California: Prepared by Lawrence Livermore Laboratory for the U.S. Energy Research and Development Administration, National *Technical Information Service publ., no. UNCL-51976,* 54 p.

Summarization of the geophysical, geochemical, and geothermal characteristics of wells located in the Salton Sea geothermal field. Includes sub-surface heat profiles for the entire geothermal field. Maps of temperature contours for specific depths throughout the field are included.

420 Palmer, T.D., Howard, J.H., and Lande, D.P., 1975. Geothermal development of the Salton Trough, California and Mexico. By Lawrence Livermore Laboatories; for ERDA TID-4500, UC-13. MCRL-51775.

A geological description of the Salton Trough followed by a chronological history of attempts to exploit the area's geothermal resources. In addition, detailed descriptions are given of all ongoing geothermal projects in the area and the organizations conducting them.

421 Papadopulos, S.S., 1975, Ther energy potential of geopressured reservoirs: Hydraulic factors, in Dorfman, M.H., and Deller, R. W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 173-192.

This is an anlysis intended to determine possible well yields in a geopressured reservoir in Hidalgo County, Texas. Also, the sensitivity of well yields to hydrogeologic factors is examined. Figures include graphs of flow rate through the well, drawdown distribution, and determination of well spacing. A section of an idealized reservoir model is shown.

422 Papadopulos, S.S., Wallace, R.H., Jr., Wesselman, J.B., and Taylor, R.E., 1975, Assessment of onshore geopressured resources in the northern Gulf of Mexico basin: USGS/ERDA Rept., U.S. Geol. Survey Circ. 726, p. 125-141.

Geopressured zones in the northern Gulf of Mexico basin are known to occur in Tertiary sediments beneath an area greater than 278,500 sq. km., extending from the Rio Grande in Texas northeastward to the mouth of the Pearl River in Louisiana. The resource potential of geopressured-geothermal reservoirs within the onshore part of Tertiary sediments under an area of more than 145,000 sq. km. along the Texas and Louisiana Gulf Coast is assessed. The study area is divided into subareas, with the geopressured zone in each area idealized as a "conceptual reservoir". The recoverability of energy from geopressured reservoirs ultimately depends on the amount of water that can be produced by wells tapping these reservoirs. Various development plans for recovering the energy are discussed.

Some useful figures include a map showing assessed Gulf Coast geopressure subareas along with data on acreage pressure, temperature and salinity conditions in each subarea, and variation of well spacing with the ratio of flow rate to the 20-year formation drawdown for each of the conceptual reservoirs.

423 Parker, C. A., 1973, Geopressures in the Deep Smackover of Mississippi: Jour. Petroleum Technology, v. 25, August, p. 971-979.
Geopressures in the interior basin of Mississippi appear to be geologically late events associated with inflation and hydrocarbon phase changes. Acids associated with these late geopressures have impressed secondary porosity in deep Smackover sandstones. Anomalous deep porosity in Mississippi need not be overpressured, and is not dependent on geopressures preserving primary porosity. By means of field examples, this paper examines diverse origins for the deep Jurassic geopressures, and contrasts them with origins of geopressures in the Gulf Coast Tertiary.

424 Parker, C. A., 1975, Deep Smackover drilling in Mississippi reveals geopressured oil and gas: Oil and Gas Jour., v. 74, no. 32, p. 95-98.
Through field examples, the author examines diverse origins for deep Jurassic geopressures in the interior salt basin of Mississippi, contrasting them with geopressures in Gulf Coast Tertiary. Unlike the latter, which result from loading and undercompaction caused by rapid deposition, the deep Jurassic geopressures appear associated with late geologic events involving inflation and hydrocarbon phase changes. A related purpose is to argue that deep Jurassic reservoirs are not a result of interparticle pores being propped open by geopressure, as happens in the Gulf Coast Tertiary, but rather are due to secondary porosity.

425 Parker, L. W., 1977, The Big Thicket of Texas: A comprehensive annotated bibliography: Sable Publishing Corp., P. O. Box 788, Arlington, Texas 76010.
A bibliography and history of the Big Thicket containing 2,258 entries. Includes sources on the land, animals, plants, people and history of the area.

426 Parker, P. L., 1974, Effects of pollutants on marine orgainisms: National Science Foundation, Office for the International Decade of Ocean Exploration, National Technical Information Service Pub., no. PB-259 354/9WP, 48 p.
The scientific results of a two-year research program, Effects of

Pollutants on Marine Organisms Program, is described in this volume. The volume summarizes the deliberations of a workshop meeting of the Program participants and invited scientists which was held in Sidney, British Columbia, Canada, on August 11-14, 1974. Research has focused on determining sublethal effects of low levels of chemical pollutants on bacteria, microalgae and animals. The chemical pollutants studied were petroleum, trace metals, chlorinated hydrocarbons and phyhalates.

427 Parker, P. L., and others, 1976, Environmental Studies, South Texas Outer Continental Shelf, 1975: Biology and Chemistry: A report to the U. S. Bureau of Land Management prepared by personnel of the University of Texas, Texas A&M University and Rice University, basic data in appendices I-II, 598 p.
An environmental survey of the South Texas Outer Continental Shelf concerned with the hydrological, geological, biological, and chemical components of the nearshore (shelf) waters of the Texas Coast. The purpose of the project was to establish environmental baselines prior to oil and gas exploration in the waters of the Gulf of Mexico.

428 Patrick, D. M., 1977, Microearthquake monitoring at Corps of Engineers facilities: Vicksburg, Mississippi, U. S. Army Engineers Waterways Expt. Sta., Soils and Pavements Lab., Tech. Rept. S-77-2.
Awareness of potential seismicity induced by the filling of large reservoirs or by the injection of fluids in boreholes has prompted the Corps of Engineers and others to conduct microseismic monitoring programs at ten damsites and one injection well. Objectives of these monitoring programs and techniques employed are discussed. The injection well is located in Childress County, Texas.

429 Patrick, W. H., Jr. and Delaune, R. D., 1976, Nitrogen and phosporus utilization by Spartina alterniflora in a salt marsh in Barataria Bay, Louisiana: Estuarine and Coastal Mar. Sci., v. 4, p. 59-64.
The effect of added inorganic nitrogen and phosphate on yield and nutrient uptake of Spartina alterniflora in a salt marsh are considered. Nitrogen increased the yield by 15%. Percent plant nitrogen derived from added inorganic compounds ranged from 41% in the early summer to 31% in September. Twenty-eight percent of the added nitrogen was recovered in the above ground portion of the plants in September. Total nitrogen concentration was increased by 25-50% by the added nitrogen. Concentration of phosphorus was increased by 20%, but no increase in yield resulted. The increased phosphorus uptake represented a very small fraction of the added phosphorus. This study indicates that the salt marsh may be deficient in nitrogen, but not phosphorus for growth

of S. Alterniflora.

430 Perkins, E.J., 1974, The Biology of Estuaries and Coastal Waters: Academic Press, N.Y., 678 p.

A general reference for estuarine research. Topics covered include: physical and chemical features; water movements; plankton; shores and sediments; sediment transport; benthos; microbenthos; meiobenthos; macrobenthos of the rocky shore; macrobenthos of sedimentary beaches; fouling and boring organisms; the inshore harvest; pollution; parameters of waste disposal; biological effects of waste disposal; and management of estuaries and coastal waters.

431 Perret, W.W., Barrett, B.B., Barney, B., Latapie, W.R., Pollard, J.F., and Mock, W.R., 1971, Cooperative Gulf of Mexico estuarine inventory and study, Louisiana, Phase I: Area description and Phase IV: Biology, Louisiana Wildlife and Fisheries Commission, New Orleans, 218 p. (NTIS: COM-72-10051).

Tabular data are presented on water volume, vegetation, stream discharge, commercial fishery operations, coastal populations, pollution, filled areas, drained areas, and navigation channels in Louisiana's estuarine zone. Comparisons are made between past years' data and recent information. Biological sampling was conducted in six estuarine study areas of Louisiana. A total of 82 trawl, 12 seine, and 28 plankton stations were sampled weekly, bi-weekly, or monthly, from April 1968 through March 1969. A total of 100 species of fishes and 19 species of invertebrates were collected. Area and seasonal distribution of these species are discussed in the following pages. Also presented are data on historical commercial fisheries.

432 Phleger, C.H., 1971, Effect of salinity on growth of salt marsh grass, Ecology, v. 52, no. 5, p. 908-911.

The coastal salt marsh grass, Spartina foliosa, was grown in nutrient solution at different salinities for eight weeks. Growth and survival was greatest in fresh water although the plant grows in sea water in its natural habitat. Protein and lipid were higher in fresh water cultured plants than in sea water cultured plants. Fresh water plants contained less sodium and more potassium than sea water plants.

433 Pigford, T.H., Keaton, M.J., Mann, B.J., and Sessler, G.L., 1975, Comprehensive standards: The power generation case: Teknekron, Inc., Berkeley, California, 360 p. (NTIS: PB 258 876/1WP).

This report presents an illustrated data base of material quantities and environmental effluents in the fuel cycles for alternative technologies of thermally generated power. The entire fuel cycle for each of ten alternative technologies is outlined for a representative power plant generating 1000 Mw of electric power. The required utilization of material resources and the fuel-cycle material quantities are indicated on a flow sheet for each technology. Includes considerations on the technology of geothermal steam.

434 Platus, D. L., Morse, C. P., and Fukuzawe, J., 1974, Rapid shutdown of failed pipelines systems and limiting of pressure to prevent pipeline failure due to overpressure, Part II, Industry survey report: Los Angeles, California, Mechanics Research, Inc., MRI-2628-TR2, Dept. Transportation, Office of Pipeline Safety, 401 p.

This report covers the industry survey portion of a study to determine the state-of-the-art for (1) rapid shutdown of failed pipeline systems, and (2) limiting of pressure to prevent failure due to overpressure. Technical summaries of shutdown and pressure limiting systems and components were prepared. These cover current shutdown and pressure limiting practices by the industry (frequency of use of various methods and equipment), and technical descriptions and analyses of typical systems and components. Promising rapid shutdown equipment was identified and detailed summaries and analyses were prepared, including operator and carrier experience, performance and reliability data, advantages, disadvantages, manufacturers, and costs.

435 Platus, D. L., MacKenzie, D. W., and Morse, C. P., 1974, Rapid shutdown of failed pipeline's systems and limiting pressure to prevent pipeline failure due to overpressure, Part I, Final technical report: Los Angeles, California, Mechanics Research, Inc., MRI-2628-TR1, Dept. Transportation, Office of Pipeline Safety, 216 p.

The state-of-the-art was determined for (1) rapid shutdown of failed pipeline systems, and (2) limiting of pressure to prevent failure. Liquid pipelines, gas transmission lines and gas distribution systems were studied. Information was obtained from a comprehensive questionnaire survey of the industry, a literature search, and other sources. The effectiveness of rapid shutdown in reducing accident effects was determined from analysis of historical data. Feasibility of a liquid spillage limitation, and relative risks in rapid shutdown vs. continued operation of a failed gas distribution facility were investigated.

436 Podio, A. L., 1976, Proceedings, Second Geopressured Geothermal

Energy Conference, Vol. 3, Reservoir research and technology: Univ. Texas, Austin, Center for Energy Studies, February 23-25, 377 p.

Advanced research and technology in well drilling, well design, well completion, well performance, data acquisition, and reservoir performance are explored, and preliminary plans with cost estimates for a geothermal test well are developed. Available drilling and completion technology and equipment are adequate to successfully complete a geopressured geothermal well. Certain long lead times can be determined based on the approximate site definition, but a detailed program design requires complete definition of the test site. Development of a geothermal reservoir simulator is necessary to properly design the test sequence and evaluate reservoir performance. Recommendations for future research are included. Numerical simulation of reservoir performance is also discussed.

Several appendices are included which give data on the following: 1) Sample application to Test Site No. 1. General description of drilling operation and cost estimates at Candelaria Field in Kenedy County, Texas. 2) Drilling and completion programs and cost estimates for depths of 14,000, 16,000 and 18,000 feet. 3) Temperature distribution and pressure losses in a geothermal well. 4) Wireline formation testing. 5) Program outline and cost estimate of rock mechanics and flow property studies.

Individual parts of this volume are cited under separate authors.

437 Podio, A. L., and others, 1976, Development of drilling, completion and testing plan for a geopressured geothermal well, in Podio, A. L., ed., Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 3, Reservoir research and technology: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 9-56.

This is a presentation of general guidelines, reommendations, and cost estimates for drilling, completing, and testing a well in a Gulf Coast geopressured geothermal reservoir.

438 Poland, J. F., 1971, Subsidence and its control, in Cook, T. D., ed., Underground waste management and environmental implications: Am. Assoc. Petroleum Geologists Memoir 18, Symposium Proc., Houston, Texas, December 6-9, p. 50-71.

This article is a discussion of land subsidence in Japan and California, and of the reduction of the rate of subsidence in these areas by reduced ground water, oil, and gas extractions, and reinjection.

Methods employed to measure the change in thickness of sediments compacting or expanding in response to change in effective stress include (1) depth-benchmark and counterweighted-cable or "free" pipe extensometers with amplifying and recording equipment, (2) casing-collar logs run periodically in a cased well, and (3) radioactive bullets emplaced in the formation behind the casings at known depths and resurveyed by radioactive detector systems at a later time.

In evaluation of potential land subsidence due to fluid withdrawal, an essential parameter is the compressibility of compactible beds. When effective (grain-to-grain) stress exceeds maximum prior (preconsolidation) stress, the compaction is primarily inelastic and non-recoverable, and the virgin compressibility may be 50-100 times as large as the elastic compressibility in the stress range less than preconsolidation stress.

If fluid pressures in a compacting, confined system are increased sufficiently to eliminate excess pore pressures in the fine-grained sediments, subsidence will stop.

439 Poljakoff-Mayber, A. and Gale, J., 1975, Plants in Saline Environments: Springer-Verlag, N.Y., 213 p.

A good general review of the problems faced by plants in saline environments. Includes a review of the salinity problem; discussions on soil, water, and salinity; responses of plants to salinity; and a general discussion. Also contains a plant index.

440 Pore, N.A., Angelo, A.T. and Taylor, J.G., 1965, Hurricane Cindy Galveston Bay tides: Washington, D.C., U.S. Weather Bur., Techniques Devel. Lab., September, Rept. #WBTN-11TDk-2, 10 p.

Hurrican Cindy of September 1963 probably produced the most completely recorded set of tide data in a bay of any United States hurricane. Hydrographs showing the water levels in Galveston Bay along with pertinent meteorological data are presented.

441 Powers, M.C., 1967, Fluid-release mechanisms in compacting marine mudrocks and their importance in oil exploration: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 1240-1254.

The application of current knowledge of clay colloid chemistry and mineralogy to the question of how water escapes from muddy sediments has led to two conclusions: (1) The alteration of montmorillonite to illite takes place after deep burial and involves the transfer of large amounts of bound water from montmorillonite surfaces to interparticle areas where it is normal water. This water transfer has an important bearing on the porosity, permeability, abnormal fluid pressure and initial release of hydrocarbons from mudrocks. (2) In deposits of primary illite, water is compacted out of clay soon after burial, before the formation of hydrocarbons comparable with those found in reservoirs. Abnormally high fluid pressures may easily be caused by a volume increase associated with the desorption of the last few monomolecular layers of water from montmorillonite during diagenesis to illite. This understanding of mineralogical characteristics makes it possible to make meaningful interpretations of data on the bulk properties of compacting mudrocks.

442 Price, D.G., Kubicek, P.F., and Enriquez, L.A., 1976, Geysers Unit 17 site specific studies: Fishery resources, water quality characteristics and stream sedimentation: Report to Pacific Gas and Electric Company, Department of Engineering Research, no. 7784.13-76, 78 p.
Studies of fishery resources, water quality characteristics, and stream sedimentation conditions were conducted to identify baseline conditions and to determine potential impacts due to construction of the Geysers Unit 17 Power Plant, proposed for development near the headwaters of Squaw Creek. It was determined that power plant construction will disturb the watershed, and that stream sedimentation was the most serious potential hazard to the fishery resource.

443 Pulish, W., Barnes, S., and Parker, P., 1976, Trace metal cycles in seagrass communities: Estuarine Processes, v. 1, p. 493-506.
Processes which make trace metals as well as other nutrients, readily available may account for the distribution of and patterns of succession in seagrass meadows. Complete inventories of Fe, Mn, Zn, and Cu were compared for five species of Texas seagrasses from study areas in Redfish Bay and Northern Laguna Madre.

444 Pullen, E.J., and Trent, L., 1968, Hydrographic observations from the Galveston Bay system, Texas, 1958-1967: Bureau of Commercial Fisheries, Galveston, Texas. Biological Laboratory. Contribution 280, 152 p. (NTIS: PB-182 757).
Hydrographic data were collected during ecological studies made from January, 1958 through December 1967 in the Galveston Bay system, Texas. The report contains the depth, location, date, time, and sample water depth from which samples were taken and corresponding measurements of water-temperature, salinity, phosphorus, nitrogen, and dissolved oxygen.

445 Pullen, E. J., Trent, W. L., and Adams, G. B., 1971, A hydrographic survey of the Galveston Bay system, Texas, 1963-1966: National Marine Fisheries Service, Galveston, Texas. Biological Laboratory. Contribution no. 315, 22 p. (NTIS: COM-71050604).

Water temperature and salinity data, taken during 1963-66, and dissolved organic nitrogen, total phosphorus, and dissolved oxygen data taken during 1964-66 from Galveston Bay, Texas were analyzed by area and habitat.

446 Ramey, J. J., 1962, Wellbore heat transmission: Jour. Petroleum Technology, v. 14, p. 427-435.

This paper presents a proposed method of calculating well-bore heat-transmission involved in injection of hot or cold fluids. The method permits estimation of the temperature of fluids, tubing and casing as a function of depth and time. The result is expressedin simple algebraic form suitable for slide-rule calculation. It is assumed that heat transfer in the wellbore is a steady-state, while heat transfer to the earth will be unsteady radial conduction. Allowance is made for heat resistances in the wellbore. The method used may be applied to derivation of other heat problems such as flow through multiple strings in a wellbore.

Comparisons of computed and field results are presented to establish the validity of this method.

447 Rare Plant Study Center, 1974, Rare and endangered plants native to Texas. Third Edition: Developed by the University of Texas' Rare Plant Study Center and Resource Management Section of the Texas Parks and Wildlife Department. 12 p.

A listing of more than 500 species of rare plants in Texas. Included is information on frequency and distribution.

448 Ratclaff, K. W., 1976, Chemical and physical characteristics of water in estuaries in Texas, October 1971 - September 1973: Texas Water Development Board, Rept. 208, 347 p.

This is a summary of data collected from Texas estuaries over a two-year peiod. It does not include Galveston Bay or the Rio Grande. The investigation describes the occurrence, source, and distribution of nutrients and physical organic and inorganic water-quality constituents. Also, current patterns, directions, and rates of water movement are recorded.

449 Reid, G. K., 1955, A summer study of the biology and ecology of East Bay, Texas: Texas Jour. Sci., v. 7, no. 3, p. 316-343.

Location is described in terms of drainage, marsh bottom composition and configuration, and tides and currents. Report includes measurements of salinity, pH, temperature, turbidity, and plankton. Aspects of the fish community are discussed considering many of the species on an individual basis, correlating occurrence with physical parameters. Includes a lising of the faunal components of East Bay.

450 Reid, G. K., 1956, Ecological investigations in a disturbed Texas coastal estuary: Texas Jour. Sci., v. 8, no. 3, p. 296-327.

A comparison of the ecological conditions in East Bay prior to and after the construction of Rollover Pass, a cut through Bolivar Peninsula on the Gulf Coast of eastern Texas.

451 Reid, G. K., 1957, Biological and hydrological adjustments in a disturbed Gulf Coast estuary: Limnol. and Oceanog., v. 2, no. 3, p. 198-212.

East Bay, an arm of the Galveston Bay system of Texas, was studied during the summers of 1954, 1955, and 1956. The first study was made with the Bay in its natural state, the second investigation followed the excavation of Rollover Pass that permitted considerable exchange between the Gulf of Mexico and the Bay, and the third study was subsequent to partial blocking of the Pass.

Considerable evidence from salinity distribution and fluctuations in population density of the dominant fish and shrimp species suggests a rapid physical and biological reversion toward the natural condition, following blocking of the pass. In addition, the presence or absence of certain fish and shrimp forms was correlated with changes in the Bay.

452 Reid, G. W., Streepin, L. E., Canter, L. W., and Smith, J. R., 1974, Brine disposal treatment practices relating to the oil production industry: Environmental Protection Agency, Oklahoma Univ., Norman, School of Civil Eng., and Environmental Sci. Proj. EPA-14020-FVW, 288 p.

A methodology is developed for economic evaluation of environmentally acceptable brine disposal systems. Specifically, a procedure is presented for determining total unit costs of alternative systems. These are then compared in order to select the least expensive, legally-permitted disposal processes. A broad and simplified discussion of resource economics is included, and disposal mechanisms and disposal coast analyses are described. Methods are included for cbtaining the necessary information for use in the anlyses. A listing is made of state regulatory agencies and their roles in administering brine disposal policies.

453 Reintjes, J. W. and Keney, P. M., 1975, Annotated bibliography on the biology of the Menhaden, Genus Brevoortia, 1963-73: NOAA Technical Department, National Marine Fisheries Service Special Scientific Report, Fisheries, no. 687, p. 1-92.

A bibliography that consists of 444 references on the classification, distribution, abundance, life history, and ecology of American Menhadens. Brief annotations and subject index are included.

454 Reintjes, J. W. and Pacheco, A. L., 1966, The relation of Menhaden to estuaries. Amer. Fish. Soc. Special Pub., no. 3, p. 50-58.

Menhaden, Brevoortia, use estuaries along the Atlantic and Gulf coasts of the United States as nursery areas for more than half of their first year of life. Physical, chemical, and biological factors affecting young Menhaden are discussed. Literature citations include most of the publications on the estuarine phase of the Menhaden's life history.

455 Reistad, G. M., 1975, The potential for non-electrical applications of geothermal energy and their place in the national economy (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VIII-13.

Electricity generation from geothermal resources presently has the major research and development focus in the U. S. Although electricity generation from these resources has the advantage of location independence, there are a number of other factors that point toward non-electrical applications having more long range potential. Some of these factors are: (1) the geothermal resource which exists at low-to-medium temperature is estimated to be much larger than that at higher temperatures; (2) a very large proportion of the basic energy needs of any industrialized nation is for heating at low-to-medium temperatures; and (3) low-to-medium temperature heating needs are difficult to meet efficiently from either electricity or fossil fuels, as is indicated by the poor thermodynamic performance of most of the present systems supplying such needs.

The major thrust of this paper is the estimation of both the amount of direct heating that could be used to meet the basic energy requirements of an industrialized nation and the temperatures that are required. The energy requirements of the U. S. are evaluated to determine the potential substitutions of geothermal energy that could result in sizeable direct applications. Evaluation is limited to uses that have temperature requirements typical of geothermal resources. Here, 250°C is considered the maximum temperature for direct applications. The aspect of geographically matching potential applications with known or potential resources is not considered. It is estimated that greater than 40% of the total energy requirements of the U. S. could be satisfied from geothermal resources with heating at a maximum temperature of 200°C when the resource is available at each application site. Similar percentages at 150°C and 100°C are 30 and 20% respectively.

456 Reynolds, G., 1970, Cooling with geothermal heat: Geothermics, Spec. Issue 2, v. 2, pt. 2, p. 1658-1661.

The author presents a case history of cooling and heating a multi-unit dwelling in New Zealand. However, they used cooled water for refrigeration instead of a chemical coolant, (i. e. ammonium absorption or LiBr absorption).

457 Richard, R. A., 1975, Total environmental control on drill jumbos: Canadians Mining Jour., v. 96, p. 54-55, 58.

The noises produced by percussion drills are of the highest intensities when compared to other operations. In addition the lubricating oil added to the compressed air results in an oil laden mist in the atmosphere. With the advent of the multiple boom Jumbos the drillers' task has been made much easier physically but the situation has been made worse as far as the environment of the drill face is concerned. The bigger drills used have resulted in increased noise intensities and the higher air comsumption results in more oil being entrained into the atmosphere. Denison Mines in Elliot Lake have recognized this problem and last fall made a request to Jarvis Clark for the development of a cab which would provide the Jumbo operator with a totally controlled environment.

458 Riemann, C. F., Rios-Castellon, L., and Underhill, G. K., 1976, Economic analysis, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 55-103.

The purpose of this paper is to present an economic evaluation of electric power production from geopressured geothermal resources in Texas. An effort has been made to obtain the most realistic data (presented here in numerous tables) concerning the investment and production costs of a geothermal power generation system sited on a model geopressured geothermal resource.

The economics of the production of electricity from geopressured geothermal generation plants are not now as attractive as generation from western coal-fired plants. The coal-fired plant, without stack-gas scrubbers, will produce electricity at approximately 70% of the busbar price of the geopressure geothermal plant. A coal-fired plant with stack-gas scrubbers will produce electricity at about 85-90% of the geopressure geothermal busbar price. However, increasing fossil-fuel prices will tend to improve the geothermal plant's economics while tending to worsen those of the coal plant.

459 Rimberg, D., 1974, Utilization of waste heat from power plants: Park Ridge, New Jersey, Noyes Data Corporation Publication, 171 p.

Present-day steam power plants in the United States discharge as waste heat, energy equivalent to approximately twice their total present electrical generating capacity. Because this waste heat is low-temperature, it is difficult to utilize. It represents a necessary, but unwanted, by-product of the energy conversion process for generating electricity.

Chapter 1 discusses possible reasons for the existance of ineffective utilization and also the means to promote efficient energy usage. Chapter 2 assesses the cause, magnitude and possible effects of heat discharges to water from steam electric power plants and related aspects of condenser cooling system operations. Chapter 3 is a discussion of the thermodynamics of the electric power generation cycle detailing the reasons for the inefficiencies in heat generation.

Although several components of the steam power plant produce unused heat at much higher temperatures, only the applications that can use 100°F water are examined in Chapters 4 and 5. These are the use of heat for food production in agriculture and aquaculture, and the use of heat for wastewater treatment.

In the past, the dissipation of waste heat was accomplished by wet and dry cooling towers and cooling ponds, lakes, and streams. These methods are now being challenged by some sectors of society, and industry is being forced to consider their environmental impact. Chapter 6 discusses the needed research necessary to integrate the complicated interactions of the physical engineering, biological and social aspects of the waste heat problem.

460 Rinehart, J. S., 1975, Geothermics: Appl. Mech. Review. v. 28, no. 8, p. 1081-1084.

This article describes the five general types of geothermal resources that can be used to generate electric power, including geopressurized reservoirs in which fresh water at high pressure is stored deep underground. The three main geothermal producing areas (Wairakei, The Geysers and Lardarello) as well as a number of pilot plants are described.

461 Rios-Castellon, L., and Underhill, G. K., 1976, Ground water survey of the Texas coastal plain, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 105-137.

The purpose of this investigation is to determine the availability of ground-water resources of the Gulf Coast Region, Texas, with particular reference to the sources of water suitable for the development of geothermal energy utilization for generation of electric power. For this purpose, the availability of water resources is important for heat rejection. The expected characteristics of the geopressured geothermal resource (lower temperatures) will result in low cycle efficiencies and hence large quantities of heat for rejection. Water resources will be very important, therefore, if evaporative cooling towers are to be used.

The Gulf Coast Region is divided into five different subregions with similar soil formations, water availability, and general climatological characteristics. Sample counties are chosen from each of these subregions for which a general description, ground water resources, ground water availability, and future utility is given. Ground water requirements for geothermal power production and the impact of geothermal energy on water resources in the Texas Gulf Coast is also covered.

462 Rios-Castellon, L. A., 1976, Surface disposal system for geothermal fluids: Univ. Texas, Austin, Master's thesis, 161 p.
This thesis presents information about the surface disposal of geothermal effluent from the potential geopressured geothermal energy utilization facilities along the Texas Gulf Coast on the Gulf of Mexico. An effort has been made to cover the subject thoroughly, including the environmental description of the area involved--the Texas Gulf Coast and Gulf of Mexico--and the physical description of a potential surface disposal system. The descriptions and technical calculations contained in the thesis are presented as guides for the preliminary conceptual design of a geothermal waste surface disposal system that could be used in the Texas Gulf Coast Geopressured Geothermal Energy Development Project.

463 Ritch, H. J., and Kozik, H. G., 1971, Petrophysical study of overpressured sandstone reservoirs, Vicksburg Formation, McAllen Ranch field, Hidalgo County, Texas: Soc. Prof. Well Log Analysts, 12th Ann. Logging Symposium Trans., Dallas, Texas, May 2-5, paper BB, 14 p.
The successful exploitation of the highly overpressured, low permeability gas-bearing Vicksburg reservoirs in the McAllen Ranch field was due to effective utilization of available engineering, research, and reservoir data, especially representative core material. The basic techniques presented and applied to the Vicksburg trend have been applied to other overpressured sandstone reservoirs.

464 Roberts, M. H., Jr., Diaz, R. J., Bender, M. E., and Huggett, R. J., 1975, Acute toxicity of chlorine to selected estuarine species: Jour. Fish. Res. Board Canada, v. 32, no. 12, p. 2525 - 2528.
Two flowing water systems designed to test the acute toxicity of chlorine in estuarine water are described: one adapted for microscopic species, the other for larger species. Acute toxicity data for several invertebrate and fish species are presented. Molluscan larvae and Acartia tonsa were the most sensitive species tested.

465 Rohlich, G. A., Galwardi, E. F., and Malish, D., 1975, Impact on Texas water quality and resources of alternate strategies for production, distribution, and utilization of energy in Texas in the period 1974 - 2000: Final Report to the National Science Foundation, Project E/S-3, by the University of Texas, 117 p.
Analysis and assessment of the impact of projected energy and water demands, and alternate fuel strategies on the water resources of the state as a whole were made for three scenarios. In addition, analyses

were made for the Colorado and Neches River basins as representing relatively different regions with regard to water resources and industrial and population concentrations. Two state overviews, the baseline scenario (Scenario I), and the market forces scenario (Scenario II), were based on data and assumptions provided by the Governor's Energy Advisory Council through the Governor's Office of Information Services. The analyses for the third scenario are based on projections of water demand made by the Texas Water Development Board from water quality information obtained from the Texas Water Quality Board.

466 Roithmayr, C. M., 1965, Industrial bottom fishery of the northern Gulf of Mexico, 1959-63: U. S. Fish and Wildlife Service Special Scientific Report, no. 518, p. 1-23.

Distribution of fishing effort, composition of landings, harvesting operations, and processing methods are described for the industrial bottom fishery of the northern Gulf of Mexico. The more important fishing grounds are located between the Mississippi River Delta and the entrance to Mobile Bay. The Atlantic Croaker contributed, on the average 56% by weight to the total annual bottomfish landings during 1959-63.

Analysis of annual production, catch per unit effort, and total fishing effort indicated that the bottomfish population maintained itself at reasonably productive levels over the 5-year period. Recommendations concerning utilization of the bottomfish resource of the area are suggested.

467 Rollo, J. R., 1960, Ground Water in Louisiana: Louisiana Water Resources Bull. no. 1, 84 p., maps.

A summary of data on ground water in Louisiana, including electric logs, chemical analyses, records of water wells, and reports on the geology and ground-water resources of Louisiana and adjacent states.

468 Rose, C. D., Harris, A. H., and Wilson, B., 1975, Extensive culture of Penaeid shrimp in Louisiana salt marsh impoundments: Trans. Amer. Fish. Soc., v. 104, no. 2, p. 296-307.

Wild and hatchery-produced shrimp were stocked in two impoundments off Bayou Jean Lacroix in 1968 and 1969. Maximum annual harvest was compared for ponds in which predators and competitors had been removed and ponds with predators and competitors. Included was a mark-recapture study and estimates of growth rates. Seasonal temperature and lunar aspects were also studied.

469 Rosenthal, H. and Alderdice, D. F., 1976, Sublethal effects of environmental stressors, natural and pollutional, on marine fish eggs and larvae: Jour. Fish. Res. Board Canada, v. 33, no. 9, p. 2047-2065.

Sublethal effects of environmental changes on marine fish eggs and larvae are reviewed. Such effects are those a) elicited through application of stress at one level of organization or development, b) recognized through the appearance of altered structure or function at a later stage of development, and c) whose significance is fully manifested as lower survival potential at a further stage of development. A number of sublethal effects are marshalled in terms of type of biological response and inferred consequences. Data suggest that a variety of stress-stressor systems may trigger a limited number of organismic responses, often appearing to involve the same physiological and biochemical mechanisms. Most sublethal effects appear to be biochemical in origin, elicited through physical or chemical change, and expressed in terms of histological, morphological, physiological, or ethological response. A need is expressed for an expanded and more unified enquiry into the origin, recognition, and significance of sublethal effects.

470 Ross, R. D., 1968, Industrial waste disposal: New York, Reinhold, Reinhold Environmental Eng. Series 340 p.
A systems approach concerned with the evaluation of any waste disposal problem and the proper selection of a process and associated equipment to solve the problem. A chapter on deep well disposal gives general characteristics.

471 Rossi, S. S., and Anderson, J. W., 1976, Toxicity of water-soluble fractions of no. 2 fuel oil and South Louisiana crude oil to selected stages in the life history of the polychaete, Neanthes arenaceodentata: Bull. Envir. Contam. & Toxicol., v. 16, no. 1, p. 18-24.
Many polychaetes are found in PHC-containing sediments contaminated by chronic (refinery effluents) or acute (spills) inputs, and as a consequence may be exposed to PHCs throughout their entire life cycle. N. arenaceodentata lacks a pelagic stage in its life cycle and therefore spends its entire life cycle within quiet-water sediments which might be moderately influenced by petroleum refinery effluents. The results indicate that the very young stages of the worm are fairly tolerant and the young adults are the most susceptible.

472 Rounsefell, G. A., 1972, Ecological effects of offshore construction: Jour. Mar. Sci., v. 2, no. 1, p. 1-81 and A1-A119.
The report evaluates current knowledge of the probable ecological effects of various types of offshore construction. The greatest dangers seem to lie in the placement of artificial islands within or too closely adjacent to estuaries where they can significantly affect water exchange, and in the proliferation of water-cooled nuclear power plants. The effects on marine biology and water quality are discussed. Included is an annotated bibliography of 284 references.

473 Sabodell, J. E., and Axtmann, R. C., 1975, Heavy metal contamination from geothermal sources: Environmental Health Prospectives, v. 12, p. 1-7.

Liquid-dominated hydrothermal reservoirs, which contain saline fluids at high temperatures and pressures, have a significant potential for contamination of the environment by heavy metals. The design of the power conversion cycle in a liquid-dominated geothermal plant is a key factor in determining the environmental impact of the installation. Reinjection of the fluid into the reservoir minimizes heavy metal effluents, but it is routinely practiced at few installations. Binary power cycles with reinjection would provide even cleaner systems, but are not yet ready for commercial application. Vapor-dominated systems which contain superheated steam have less potential for contamination but are relatively uncommon.

Field data on heavy metal effluents from geothermal plants are sparse, and obscured by contributions from "natural" sources such as geysers and hot springs which often exist nearby. Insofar as geothermal power supplies are destined to multiply, much work is required concerning their environmental effects, including those caused by heavy metals.

474 Salzmann, H., 1977, Fluid and soil mechanics processes during hydraulic dredging: Texas A&M Univ., Sea Grant Coll., Sea Grant Rept. #77-204, CDS Rept., no. 184, 162 p.

Hydraulic and soil mechanics processes during bottom suction with a hydraulic dredge were investigated by laboratory study. Several experimental models were developed with the objectives of obtaining information on processes between water (suction flow) and soil during dredging, influence of soil type, influence of the shape of the suction head, and influence of supplementary pressured water jets upon the output of solid materials. Several figures and diagrams accompany the paper.

475 San Diego Gas and Electric Company, 1976, A geothermal loop experimental facility in the Imperial Valley: Energy Research and Devel. Adm. and San Diego Gas and Electric Company, Publicity Pamph.

The Niland Geothermal Loop experimental facility, producing 10 megawatts, will test the application of a binary cycle system for production of electricity by using a high temperature, high salinity geothermal resource. The reinjection of cooled brine back into the reservoir will also be tested, and the potential of the Niland Geothermal Reservoir will be assessed. Included are aerial photos of the plant and a diagram of the closed cycle system.

476 Scalf, M. R., Keeley, J. W., and La Fevers, C. J., 1973, Ground water pollution in the South Central States: Ada, Oklahoma, Robert S. Kerr Environmental Research Lab., Natl. Ground Water Research Program, Rept. #EPA-R2-73-268, 191 p. (Available from Government Printing Office, EPI. 23/2: 73-268).

A study was conducted to determine the ground-water pollution problems in the states of Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. Information was obtained through review of the literature and through interviews with engineers, scientists, and governmental officials concerned with water pollution in the five states of the project area. Natural salinity was the greatest factor affecting the quality of ground water of the region. Disposal of oil-field brines was the most widespread source of man-made pollution. Other causes of ground-water pollution included poor well construction and abandonment procedures, over-pumping, irrigation return flows, and land disposal of solid and liquid wastes.

477 Schauers, J. A., 1974, Engineering approach to the selection of a pipe line coating: West Virginia Univ. Eng. Expt. Sta. Bull., no. 113, p. 46-49.

One effective means of combating corrosion on underground steel pipe lines is by the application of coatings. The coating establishes a barrier between the pipe line and its immediate environment. The author explains the necessary procedures (soil and water survey, coating selection, preparation and application of coating, and some methods of cathodic protection of a coated pipe line), and gives three basic steps to follow.

478 Schmidly, D. J. and Melcher, B. A., 1974, Annotated checklist and key to the cetaceans of Texas waters: Southwest. Naturalist, v. 18, no. 4, p. 453-464.

Data are presented on six families and 16 species of cetaceans known to inhabit Texas waters. Exact localities where these whales and dolphins have been sighted or washed ashore are given. Extention of previously known range is indicated for several species. A simplified key is presented to aid in the identification of each species.

479 Schmidt, G. W., 1973, Interstitial water composition and geochemistry of deep Gulf Coast shales and sandstones: Am. Assoc. Petroleum Geologists Bull., v. 57, no. 2, p. 321-337.

Interstitial water from shales and sandstones shows a contrast in concentration and composition. Sidewall cores of shales were taken every 500 feet between 3,000 and 14,000 ft. in a well in Calcasieu Parish, Louisiana, which encountered abnormally high fluid pressures just below 10,000 ft. Significant differences between the total dissolved solids concentrations in waters from normally pressured sandstones (600-18,000 mg/l) and highly pressured sandstone (16,000-26,000 mg/l) were noted. Shale pore water has a lower salinity than the water in the adjacent normally pressured sandstones, but the concentrations are more similar in the high pressure zone. Shale water generally has a concentration order of $SO_4 \geq HCO_3^- > Cl^-$, whereas water in normally pressured sandstone has a reversed concentration order.

Conversion from predominantly expandable to non-expandable clays accelerates near the top of the high pressure zone, which appears correlative with a major temperature gradient change, an increase in shale porosity (decrease in shale density), a lithology change to a massive shale, an increase in shale conductivity, an increase in fluid pressure, and a decrease in the salinity of the interstitial waters.

The data presented suggest that the clays subjected to diagenetic change release two layers of deionized water, and that this released water may be responsible for the lower salinity of the water found in the high pressure section.

480 Schmidt-Nielsen, B., 1974, Osmoregulation: effect of salinity and heavy metals: Fed. Proc., v. 33, no. 10, p. 2137-2146.

This paper deals with osmoregulation and effects of mercury on aquatic organisms. Some of the toxic effects of mercury on aquatic life undoubtedly are due to interferences with the ability of the organism to osmoregulate, but because of the fact that mercury binds with sulfhydryl groups in general, it has an inhibitory effect on a wide spectrum of enzymes and it is difficult to separate out the specific effects on osmoregulation. Mercury compounds also inhibit the ion transport enzyme Na-K-activated ATPase and interfere with the osmoregulating mechanisms of aquatic organisms.

481 Schubel, J. R., 1974, Effects of exposure to time-excess temperature histories typically experienced at power plants on the hatching success of fish eggs: Estaurine and Coastal Mar. Sci., v. 2, p. 105-116.

Four species of fish eggs were tested under temperature-time histories as might be experienced by organisms carried through a power plant or entrained in the plume. Several different states of development were tested. It was concluded that exposure of fish eggs of the species and stages of development tested to these time-temperature histories did not significantly affect their hatching success.

482 Seneca, E. D., 1972, Seedling response to salinity in four dune grasses from the outer banks of North Carolina: Ecology, v. 53, no. 3, p. 465-471.

Tolerance to salt in the substratum was determined in seedlings of four perennial dune grasses. Based on seedling growth response, the order of decreasing salt tolerance for the four species is Spartina patens, Panicum amarulum, Uniola paniculata, and Ammophila breviligulata. This pattern correlates well with performance in nature.

483 Shafer, G. H., 1968, Ground-water resources of Nueces and San Patricio Counties, Texas: Texas Water Devel. Board Rept. 73, 129 p.

The principal water-bearing units in Nueces and San Patricio Counties are the Goliad Sand, Lissie Formation, and Beaumont Clay (the Gult Coast aquifer). The units crop out in belts that roughly parallel the coast and dip to the southeast at an angle greater than the slope of the land surface.

Ground water in the two counties moves southeastward from the areas of recharge to areas of discharge. Several communities used ground water for public supply, but the largest public supplies are obtained from the Nueces River. During 1964, about 17,500 acre-feet (15.6 million gallons per day) of ground water was pumped for all purposes in the two counties.

Aquifer tests show that the coefficient of transmissibility ranges from 1,500 to 24,000 gallons per day per foot in the Gulf Coast aquifer.

Small additional supplies of ground water, perhaps on the order of a few million gallons per day, are probably available for development in the two-county area without depleting the aquifer. The area most favorable for additional development is north and northwest of Sinton in San Patricio County.

Large quantities of moderate saline water are available for development in the two-county area. The economic use of this water depends on the development of economic demineralization processes.

The most satisfactory method of salt-water disposal to prevent contamination of ground water is through the use of injection wells, but in 1961, only 23.9% of the total quantity of salt water produced from oil wells in Nueces County and 9% of that produced in San Patricio County was disposed of by this method.

Included are maps locating the base of the fresh to slightly saline water zones, and the thickness and permeability of the water bearing formations. Records of selected water wells and drillers logs are given.

484 Shafer, G. H., 1970, Ground water resources of Aransas County, Texas: Texas Water Devel. Board, Rept. 124, 80 p.

The aquifers that yield water to Aransas County wells are those of the Gulf Coast aquifer, which is mostly of Pliocene and Pleistocene age, and underlies the entire county; the Pleistocene barrier island and beach deposits, which are restricted to the peninsulas; and the Holocene barrier island deposits, which are restricted to St. Joseph Island.

Almost all ground water needed for public supply and industrial use is obtained from the Gulf Coast aquifer that underlies Live Oak Peninsula. During 1966, about 1,600 acre-feet or 1.4 mdg (million gallons per day) of ground water was pumped for all purposes in the county. Aquifer tests show that the coefficient of transmissibility of the Gulf Coast aquifer beneath Live Oak Peninsula averages about 3,000 gpd (gallons per day) per foot. The sand that underlies Live Oak Peninsula contains about 600,000 acre-feet of fresh and slightly saline water. Of this volume, about 300,000 acre-feet is recoverable, but is subject to contamination by salt-water encroachment. To prevent this supply from being depleted and contaminated, pumpage should not exceed about 11,000 acre-feet annually.

The most satisfactory method of disposal of salt water is by the use of injection wells, but in 1961 only 500 barrels (0.06 acre-foot) of salt water produced from oil wells in Aransas County was disposed of by this method.

Numerous maps include location of the base of slightly and moderately saline water, and potential for ground water development. Tables include source and significance of dissolved mineral constituents and properties of water, water levels in wells, chemical analyses, and drillers' logs.

485 Shinn, J. H., 1976, Status of ecosystem quality studies, IVEP. Unpublished, 15 p., maps.
A discussion of the team effort in the California are on monitoring environmental effects of geothermal energy production in the Imperial Valley, Considers several sites and situations including freshwater, saltwater, and die-offs caused by brine runoff.

486 Siegal, B. A. and Harrel, R. D., 1976, Community metabolism in a refinery holding pond: Jour. Water Pollution Control Fed., v. 48, no. 10, p. 2249-2258.
The most important factor regulating community metabolism was the toxicity of the untreated waste effluent. No seasonal correlation occurred. The refinery holding pond removed most objectionable wastes except for sulfides and high concentrations of algae. Lowering of toxicity could be accomplished by separating and aerating untreated wastes before they enter the main holding pond. Deepening, baffling, and construction of a polishing pond would remove sulfides and excessive algae.

487 Silberberg, I. H., 1976, Reservoir Fluid Sampling and Analysis for a Geopressured Geothermal Well, in Podio, A. L., ed., Proceedings, in Second Geopressured

Geothermal Energy Conference, Volume 3, Reservoir Research and Technology: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 59-82.

The objective of sampling the geopressured geothermal well is to obtain a representative sample of the reservoir fluid from which composition and physical properties may be accurately determined. Dissolved gases, salts, silica, and other organic chemicals are important from the standpoint of plant design, resource uses, and disposal of geothermal reservoir water. Characteristics of pressure, temperature, and dissolved components are discussed, and several sampling techniques are described.

488 Silverman, D., 1977, Corpus delicti: Univ. Texas Student Publications Maverick, no. 1, p. 8.

Summarizes recreational uses and values, particularly for fishing, in the northern Padre Island beach area near Corpus Christi. Describes increased offshore oil and gas activity in the area and the impacts of this on the beach environment--both visual (rigs visible from beach) and physico-chemical-aesthetic-(oil sludge on beaches). Describes decrease in sport fishing success in recent years.

489 Silvey, J. K. G., Abshire, R. L., and Nunez, W. J., III, 1974, Bacteriology of chlorinated and unchlorinated waste water effluents: Jour. Water Pollution Control Fed., v. 46, no. 9, p. 2153-2162.

This study designed to investigate the bacteriology and chemical effects of chlorine treatment on waste effluents discharged into the Trinity River, Texas. There is a discussion on the effectiveness of chlorination on the various bacteria. Chlorinated hydrocarbons were detected in the river as a result of chlorination; however, their effects on the microbiota and the ecology of the river have not been determined.

490 Simmons, E. G., 1957, An ecological survey of the upper Laguna Madre of Texas: Pub. Inst. Mar. Sci. Univ. Texas, v. 4, no. 2, p. 156-200.

The investigation includes a history of the Laguna, fish mortalities, and red water. Physical characteristics are discussed in terms of shore features, the watershed, bottom types, hydrology, and the biological components. Interrelationships are considered for: hydrology and meteorology; tidal effects on salinity; salinity and temperature; salinity, temperature, and fauna; salinity to flora and fauna; and flora to fauna. Also considered are winds and currents.

Species of the survey are listed and discussed in terms of temperature and salinity, distribution and relative abundance. The bay system is unique in that it is characterized by hypersaline conditions.

491 Simmons, G. M., Armitage, B. J., and White, J. C., 1974, An ecological evaluation of heated water discharge on phytoplankton blooms in the Potomac River: Hydrobiologia, v. 45, no. 4, p. 441-467.

The influence of thermal discharge from the Virginia Electric and Power Companies Possum Point Power Station on the density and diversity of algae in Quantico Creek and the mainstream of the Potomac River is investigated. No evidence that the heated discharge stimulates or contributes to the algal blooms present in the river is found. Major algal blooms are caused by nutrient loadings from upstream areas.

492 Sims, R. R., Jr. and Presley, B. J., 1976, Heavy metal concentrations in organisms from an actively dredged Texas bay: Bull. Environmental Contamination and Toxicology, v. 16, no. 5, p. 520-527.

Considers the heavy metals trapped in sediments and the effects of dredging these sediments and the associated metal release on the concentration of these metals (As, Cd, Cu, Pb, Hg, Zn) in the tissues of molluscs, crustaceans, and certain boney fishes. Organisms were taken from areas within and near San Antonio Bay.

493 Skidaway Institute of Oceanography, 1973, Research to determine the environmental response to the deposition of spoil on salt marshes using diked and undiked techniques: Skidaway Inst. Oceanography, Savannah, Georgia, 196p. (NTIS: AD-763 920).

The study included: water quality changes in relatively polluted areas during dredging; the effects on water quality of dredge spoil impoundment; processes responsible for water quality changes during dredging and after dredge spoil disposal; significant sediment parameters which can be measured that would give some basis for predicting water quality changes during dredging; dredging effects on fish and macroinvertebrates; and effects of dredging on benthic infaunal populations.

494 Smalley, A. E. and Thien, L. B., 1976, Effects of environmental changes on marsh vegetation with special reference to salinity: Tulane University, New Orleans, Louisiana, 112 p. (NTIS: N76-22616/6ST).

A literature survey primarily concerned with brackish and salt marshes located along the eastern coast of North America and the Gulf Coast. The review concentrates upon the vegetation of the marshes, particularly in regard to distribution, composition, succession, and productivity. Special efforts were made to include major works concerned with the Louisiana and Mississippi coastal marshes.

495 Smith, M., Aamodt, R. L., Potter, R. M., and Brown, D. W., 1975, Man-made geothermal reservoirs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-40.

Many drilled holes encounter rock at usefully high temperatures but produce little or no natural steam or hot water. The energy contents of these "dry" geothermal reservoirs is enormous and, if means can be found to extract and use it economically, it can contribute significantly to satisfying the world's energy needs.

One way to accomplish this is to inject water into the hot rock through one hole, permit it to circulate through natural or man-made flow passages, and recover it as steam or hot water through another hole. The major problems are those of avoiding excessive water loss if natural permeability is high or, if it is low, of creating openings for fluid circulation and enough surface to permit extraction of heat at a useful rate for a usefully long time.

The possibilities, problems and engineering requirements of such man-made geothermal systems are now being investigated in the hot granites underlying the Jemez Plateau of northern New Mexico. These contain many natural fractures which, however, at most horizons are well sealed so that *in situ* permeabilities are generally low. Hydraulic fracturing--a promising method of creating flow channels and new surface--has been accomplished at pumping pressures less than 175 bars both at 760 m (rock temperature 100°C) and at 2040 m (rock temperature 146°C). The fractures produced have been essentially vertical and rate of water loss from them has been low.

Additional experiments are now in progress at 2920 m, where the rock temperature is 197°C. Results will be reported at this symposium.

496 Smith, W. G., 1970, *Spartina* die-back in Louisiana marshes: Coastal Studies Bull., Special Sea Grant Issue, no. 5, p. 89-96.

"Die-back" is a term applied to degeneration and death of large areas of *Spartina townsendii* marshes in England. What appears to be the same condition affects *S. alterniflora* marshes in Louisiana and possibly elsewhere in North America. Several factors are likely to be involved and should be assessed in future work. These include: 1) excess salinity, 2) pathogenic organisms, 3) lack of available iron, 4) hydrogen sulfide toxicity, 5) change of tidal regime, and 6) pollution. It is especially important that the effects of pollution and alteration of tidal regime through dredging be investigated.

497 Snieszko, S. F., 1974, The effects of environmental stress on outbreaks of infectious diseases of fish: Jour. Fish. Biol., v. 6, p. 197-208.

Infectious diseases of fishes occur when susceptible fishes are exposed to virulent pathogens under certain environmental stress conditions. Very little research has been carried out to show the effect of pollution on outbreaks of infectious diseases of fishes. Therefore, examples taken from the literature were selected and reviewed to show the coincidence of infectious diseases with stress caused by temperature, eutrophication, sewage, metabolic products of fishes, industrial pollution, and pesticides.

498 Soil Conservation Service, 1972, Cameron-Creole watershed, Louisiana, Final environmental impact statement: U. S. Dept. Agriculture, Soil Conserv. Service, February 22, 1972, 73 p.

The project described includes 19 miles of levee, 35 miles of channels, and 6 water control structures. These interdependent measures will exclude excessively saline water from 100,800 acres and maintain desirable water levels and salinity ranges on the area. Land use change caused by the project includes 600 acres of marsh to construct the levee and 400 acres to construct or rehabilitate the channel. This document contains useful environmental information that can be applied to the geopressured geothermal project.

499 Spotila, J. R., 1976, Thermoregulation and temperature relations of alligators and other large ectotherms inhabiting thermally stressed habitats. Annual Progress Report, July 1, 1975-June 30, 1976, State University of New York, 18 p., (NTIS: COO-2502-5).

The effects of radiation and convection on the equilibrium body temperatures of alligators have been determined. Gaping has been shown to be an effective thermoregulatory device for retarding heat gain in the heads of these animals. Initial time dependent experiments have been completed and ketamine hydrochloride has been shown to be an effective anesthetic for alligators. Evapomtive water loss rates have been measured as a function of size, temperature and wind speed for the turtle Chrysemys scripta. Convection coefficients have been determined and climate spaces are being formulated. Field studies are under way at the Savannah River Ecology Laboratory. Convection coefficients for largemouth bass, Micropierus salmoides change as a function of temperature and water speed. Steady state heat energy budgets have been computed for this fish. The effects of arsenic and temperature on the temperature tolerance of larval muskellunge, Esox masquinongy, have been determined. The thermal tolerances of several species of minnows have also been measured. The role of the skin in the control of evaporation from amphibians and reptiles has been assessed. During the past year one article has been published, two are in press, one is in review, and eight are in preparation. Five masters theses will be completed by July 1976.

500 Squier, D. P., Smith, D. D., and Dougherty, E. L., 1962, Calculated temperature behavior of hot-water injection wells: Jour. Petroleum Technology, v. 14, p. 436-440.
A system of differential equations describing the temperature behavior of fluid injected at constant surface temperature in a well is derived and solved analytically. A formula for the fluid temperature at any time and depth is given, as well as a special formula valid for long times. These formulas are used to calculate temperatures for several typical cases. The results indicate that, initially, the temperature of the water entering the formation is considerably lower than the injection temperature. This condition lasts for only a short period--less than three days for most cases of practical interest. Following this highly transient period, during which the temperature of the fluid entering the formation builds up to about 50 to 75 percent of the injection temperature, the system enters a quasi-steady state in which the temperature changes are very slow. After several years, the bottom-hole temperature will still be 50° to 100°F lower than the injection temperature, but the heat losses may be tolerable.

501 Stanley, J. G., 1973, Mucus and freshwater osmoregulation in anadromous fishes and relationships to mortalities in the Alewife: Wisconsin Univ., Milwaukee, 29 p. (NTIS: COM-74-10164/3).
The Alewife (Alosa pseudoharengus) tolerates 10 C changes in temperature and has an acute upper lethal temperature well above those normally encountered in the Great Lakes. Thermal condition per se are unlikely to cause the mass mortality often seen in this species. Low plasma sodium levels were found associated with the moribund state and with fungal infections. Numbers of epidermal mucous cells did not generally correlate with changes in electrolyte levels. However, laboratory-held fish had high plasma sodium levels and increased number of epidermal mucous cells.

502 State of Louisiana, 1972, Acts Establishing the Stream Control Commission: State of Louisiana, Title 36, Chapter 3, May 1, 14 p.
These acts authorize the establishment of the Stream Control Commission, and define the duties of the commission in regulating and controlling pollution of State surface waters by noxious or poisonous substances, including oil, salt water, noxious or poisonous gases, and untreated wastes, etc.

503 Stream Control Commission, 1953, Rules governing disposal of waste oil, oil field brine, and all other materials resulting from the drilling for, production of, or transportation of oil, gas or sulphur: State of Louisiana, Amended January 27, 1953, 6 p.
Under authority of section 1435, chapter 3, part 1 or title 56, Louisiana

revised statutes of 1950, the following rules briefly are:

1. Pollution hazards shall not result from the disposal of oil and oil bearing mixture wastes.
2. No oily fluids shall be discharged on the ground or into bodies of surface water.
3. Producing wells and drilling barges shall be equipped with certain safety devices to avoid spillage or loss of oil.
4. Oil tanks in the vicinity of dwellings or people must be surrounded by a dike (fire wall) or retaining wall.
5. Barges, other equipment, and machinery used for the transportation of oil shall be in first class condition to avoid spillage.
6. All oil shall be removed from oil field brines before discharge.
7. No oil field brine shall be discharged into a body of water or on the ground when the Streams Control Commission determines such a discharge would be a pollution hazard.
8. Whenever possible, oil field brines shall be disposed of through disposal wells to underground formations below the fresh water level. The wells shall be constructed so as not to pollute any fresh water horizons.

504 Stauffer, R. E., and Jenn, E. A., 1975, Arsenic-phosphorus chemistry of Yellowstone geothermal waters (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 29-29 May 1975, Abstract volume, IV-14.

Hot spring waters and drainages in seven thermal basins of Yellowstone National Park were analyzed for both As and P using the molybdate blue procedure the the selective arsenate reducing agent meta-bisulfite-thiosulfate. PO_4-P concentrations in all of the thermal waters were low (mean = 4mg P/m^3) in contrast to literature values which are generally orders of magnitude larger, apparently biased by arsenate. Total arsenic was partitioned into arsenite (III) and arsenate (V) based on a persulfate oxidation of arsenite in an autoclave. The III/V ratio increased dramatically with higher sulfide levels. The sample preservation method affected the III/V ratios, with acidified samples showing evidence of "preserving" high ratios for sulfide-rich spring waters. Total arsenic was positively correlated with Cl both within thermal basins and between basins. The Mammouth and Shoshone Basins had the lowest total arsenic levels (means + 730 and 780 mg/m^3, respectively) in keeping with this general As/Cl relationship. The Norris Basin had the highest total arsenic concentrations (3,220 mg As/m^3), followed by the West Thumb Basin (2,120 mg As/m^3). Total arsenic acted conservatively in hot spring drainages in the Lower Geyser Basin. However, the III/V ratio increased dramatically down drainages indicating arsenite oxidation. The differential toxicities of arsenic species, the variable III/V ratios, and the very large As/P ratios all suggest that arsenic is important ecologically in geothermal waters. Total arsenic levels at the park boundary were 340 mg As/m^3 (7 times the public health rejection limit as As in drinking water), of which 40% was As III; thus the mass transport of arsenic out of Yellowstone National Park via the Madison River was calculated to be 165,000 kg/year.

505 Steeples, D. W. and Iyer, H. M., 1975, Location and estimation of volumes of anomalously hot material beneath some geothermal areas from teleseismic P-delays (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, III-83.

Relative arrival times of distant earthquakes at seismic arrays were used to investigate the three dimensional seismic velocity structure in four geothermal areas. Our data at Yellowstone Park, Wyoming, indicates low-velocity material that penetrates to at least 400 km depth. At Long Valley caldera, California, the source of the low-velocity anomaly is less than 40 km deep and comparable to the size of the resurgent part of the caldera in areal extent. Limited data from The Geysers and Imperial Valley, California, suggest relative teleseismic P-delays of 1/2 to 3/4 second that are probably caused by crustal sources.

Ray tracing methods allow the calculation of the approximate volume of anomalous material. Volume constraints so obtained place limits on the minimum velocity decrease required to satisfy the observed travel-time anomalies. The velocity decreases can then be used to estimate temperature. From the volume calculation and the temperature estimate, one can approximate the total heat anomaly of some geothermal areas. This approximation is limited by the absence of laboratory velocity data of appropriate rocks at up to 10 kilobars and several hundred degrees centigrade.

506 Stoker, A. K. and Kruger, P., 1975, Radon in geothermal reservoirs (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-42.

Radon release from geothermal reservoirs depends on the concentration and distribution of radium, the emanation properties of the radon, and the flow characteristics in the reservoir. At steady state, the radon concentration in produced geofluids is a function of the volumetric emanating power and the effective porosity. Thus, radon may serve as a subsurface tracer in geothermal reservoir engineering for evaluating the effectiveness of stimulation techniques which change the value of these parameters. Because of its radioactivity, radon release is also of environmental concern. Several sampling and measurement techniques were evaluated to provide representative values of radon concentration for engineering and environmental studies. Results showed that radon concentration in geofluids from several geothermal reservoirs varied significantly with time. At production rates, the concentration of radon relative to both the condensate and the carbon dioxide component of the non-condensable gases varied not only between wells in a given field but also within a single well. Data at several flow rates indicated a possible dependence of effective emanating power on formation pressure. The effect of changing flow rate on radon concentration may be predicted by theory. Tests during drawdown calibrations indicated an approach to steady-state concentration, perhaps independent of flow rate. The environmental impact of radon release to the atmosphere appears to be small and indistinguishable from the release of radon by natural emanation from the surrounding land mass.

507 Stokes, G. M., 1974, The distribution and abundance of Penaeid shrimp in the Lower Laguna Madre of Texas, with a description of the live bait shrimp fishery: Texas Parks and Wildlife Department Technical Series, no. 15, p. 1-32.

Penaeid shrimp were sampled in the Lower Laguna Madre of Texas from November 1970 through October 1972. At least once a month 47 otter trawl stations and 23 bar-seine stations were sampled. Water samples were taken with each shrimp sample. Live bait shrimp dealers were interviewed monthly to determine the extent and value of this fishery.

508 Straughan, D., 1976, Sublethal effects of natural chronic exposure to petroleum in the marine environment: Final Report of the American Petroleum Institute, Environmental Affairs Department, API Pub., no. 4280, 119 p.

Coal Oil Point, an area of natural oil seepage in the Santa Barbara Channel, was compared with control sites that were not chronically exposed to natural oil seepage. Several control sites were used throughout these studies in order to eliminate variables that could parallel oil dosage differences. A preliminary study of sites was also conducted to eliminate areas influenced by other major pollutants (heavy metals, chlorinated pesticides).

These studies were designed in terms of inter-species comparisons and not inter-community comparisons. They also encompassed most segments of the environment, most invertebrate groups, and most habitat types. Species chosen were sedentary in their habits to ensure that specimens were exposed to conditions in the area and were not transitory migrants.

509 Strawn, K. and Johnson, K., 1973, Final report on occurrence and abundance of fishes in the intake and discharge areas of the Cedar Bayou power station before and during the first year of plant operation: Report to Houston Power and Light Company of Texas A&M University, 348 p.

Fish abundance, distribution and species composition was determined in the intake and discharge areas before and after operation of the power plant began. Initial conditions of Cedar Bayou were determined by municipal sewage outfall, and brine flow from industrial wastes resulting in high salinity and low dissolved oxygen. Fluctuations in abundance and distribution of fishes appeared to be independent of the plant operations in the intake, but in Cedar Bayou, population densities and species composition increased after plant operations began.

510 Strawn, K. and Reimer, R., 1973, Abundance, distribution and injury of four decapod crustaceans collected from Dickinson Bayou and Bay and the revolving screens, intake and discharge canals of the P. H. Robinson generating station: Report to Houston Power and Light Company by Texas A&M University, 74 p.

The commercially important crustaceans: *Penaeus aztecus*, *P. setiferus*, *Callinectes sapidus*, and *C. similis* were considered. They seemed to prefer salinities above 15 ppt. Their presence in the collecting area appeared to be related to salinity changes. Maximum summer temperatures appeared to be lethal (40 C). Fewer animals were collected at these high temperatures and at low winter (18C) temperatures. More were collected in the discharge area than in the intake. There was a definite annual cycle in the occurrence of species. Injury due to plant operation did not seem to be significant.

511 Strawn, K., Aldrich, D. V., and Jackson, W. B., 1974, Distribution and abundance of shrimps, crabs, and fishes in the cooling lake of the Cedar Bayou electric power station: Report to Houston Power and Light Company by Texas A&M University, 137 p.

Distribution and abundance of shrimp, crabs and fishes in the cooling lake were correlated with temperature, salinity, turbidity, and dissolved oxygen. The most abundant species were White Shrimp, Grass Shrimp, and Atlantic Croaker. Fluctuation in abundance and distribution of species within the cooling lake was dependent upon heated effluent temperature, season of the year, salinity and substrate composition. Two species were observed to reproduce in the lake. *Spartina* beds died within the lake soon after it was flooded.

512 Strawn, K., Aldrich, D. V., and Linder, D. R., 1974, The culture of marine fish and their use as biological monitors of water quality in ponds receiving heated discharge water from a power

station: Report to Houston Power and Light Company by Texas A&M University, 345 p.

Pinfish, Spot, Atlantic Croaker, Black Drum, Redfish, Spadefish, Striped Mullet, White Mullet, and Southern Flounder were reared in ponds receiving constant flow from the discharge channel of the Cedar Bayou generating station. The purpose was to monitor water quality of the discharge and to determine its usefulness in mariculture. Temperature, salinity, and dissolved oxygen were monitored daily. Fish were sampled to determine growth, survival, condition, and length-weight relationships.

513 Strawn, K., Aldrich, D. V., and McBee, J. T., 1975, Final report on species composition, distribution, and abundance of macrobenthic organisms in the intake and discharge areas before and after the construction and operation of the Cedar Bayou electric station: Report to Houston Power and Light Company by Texas A&M University, 204 p.

Data from 1969 to 1973 were analyzed to determine species composition, distribution, and abundance of organisms before and after the plant began production. Cluster analysis was used to analyze data. Periods of low and high salinity were related to the abundance and frequency of some species. The only effect of the plant in the discharge area was a change in species composition associated with scouring of the substrate by discharge effluent.

514 Strawn, K., Aldrich, D. V., and Quarberg, D. M., 1974, Report on the culture of Brown Shrimp, Penaeus aztecus, in ponds receiving thermal effluent from a power plant: Report to Houston Power and Light Company by Texas A&M University, 225 p.

Two ponds were stocked with juvenile Brown Shrimp and an attempt was made to study the effect of water quality of the thermal effluent and to evaluate the potential mariculture benefit of the effluent. Survival was under 5%, growth less than 0.6 mm/day, and production only 0.53 and 1.59 kg/ha. It was determined that survival, growth rates and food conversion were all inversely related to stocking density.

515 Strawn, K., Johnson, K.W., and Jones, T.L., 1975, Species composition, distribution, and abundance of macrozooplankton in the intake and discharge areas after construction and operation of the Cedar Bayou electric power station: Report to Houston Power and Light Company by Texas A&M University, 217 p.

Data taken prior to the power plant operating are compared to data collected from 1971 to 1972 during operation of the plant. Most of the species increased in abundance after the beginning of operations. There was also some correlation of increased abundance with high salinity values during certain periods of the study. High rainfall runoff also had an effect on the results and is related to the abundance of other species. Ruppia maritima disappeared from the discharge area. It was concluded that the power plant had little effect on the zooplankton and that changes were due to natural phenomenon.

516 Strawn, K., Johnson, K. W., and Poff, M. J., 1973, Species composition, distribution, and abundance of macro-benthic organisms in the intake and discharge areas after construction and operation of the Cedar Bayou Electric Power Station: Report to Houston Power and Light Company by Texas A&M University, 300 p.

Data collected prior to the plant operating are compared to intake and discharge areas during 1971-72 while the plant was operating. Species lists are included. Changes in the species composition, distribution, and abundance were correlated with salinity, temperature, scouring, changes in vegetation and general outflow of the plant. Some organisms showed abundance levels which were correlated with natural changes in the estaurine environment.

517 Strawn, K., Reimer, R., and Matlock, G. C., 1972, Final report on fish condition as an indicator of water quality in Upper Galveston Bay system, Texas: Report of Houston Power and Light Company by Texas A&M University, 255 p.

Determined fish condition on Bay Anchovy, Largescale Menhaden, and Atlantic Croaker collected in April, June, September, and December of 1970 and 1971. These data were compared to temperature, dissolved oxygen, salinity, pH, and turbidity. Conclusion was that the water quality had improved in the plant discharge area (Cedar Bayou) since the plant began operation.

518 Strawn, K., Reimer, R., and Williams, G. E., III, 1972, Final report on the species composition, distribution, and abundance of macrobenthic organisms in the intake and discharge areas of a steam-electric generating station before and during initial start-up: Report to Houston Power and Light Company by Texas A&M University, 260 p.

Biological data were correlated with temperature, salinity, dissolved oxygen, pH, turbidity, and tidal movements. Climatic conditions were also considered. The discharge area proved to be the most productive, and the intake areas the least. These differences were attributed to degree of pollution in each area, type of substrate, available nutrients, and physical differences in the areas. There was a localized clam kill at the mouth of the discharge area, probably caused by the inital pumping of brine. The pumping activity improved the hydrological conditions of Cedar Bayou during the test operation of the facility. Increased salinity in the study area reflected the abundance of some organisms and resulted in the demise of others.

519 Strawn, K., Johnson, K., McBee, T., DeBusk, J., Williams, G., and Holt, S., 1973, Progress report for 1972. Species diversity and abundance of the bottom fauna, macroplankton, commercially important crabs and shrimp, and fishes before and after the construction of the Cedar Bayou generating station: Report to Houston Power and Light Company by Texas A&M University, 369 p.

Comparison of data collected in the 1971 study with that collected in 1972. Macro-benthos decreased in abundance, probably due to a decrease in salinity. Macro-zooplankton also decreased. Crustacean data revealed a decrease in Brown and White Shrimp abundance, while Grass Shrimp increased. Blue Crabs exhibited both increases and decreases during the period. There appeared to be a seasonal avoidance of the discharge plume.

Fish data indicate an increase in the killifishes and a decline in the numbers of sport and Sand Trout. Menhaden and Croaker appeared to remain relatively stable as to abundance.

520 Stream Control Commission, 1968, Order of the State of Louisiana Stream Control Commission: Baton Rouge, Louisiana, Stream Control Commission, 1 p.

Effective July 1, 1968, no oil field wastes, including salt water, produced by gas or oil field operations in the State of Louisiana are allowed to flow into bodies of water in the state unless the Commission judges that the waters are normally saline, tidally effected, brackish or are unsuitable for human consumption or agricultural purposes.

521 Stream Control Commission, 1973, Water quality criteria: State of Louisiana, Stream Control Comm., 66 p.

Included are tables listing specific criteria and standards for Louisiana's interstate streams, coastal waters, and streams discharging into coastal waters. The policies and regulations enforced by the Stream Control Commission are explained, followed by sampling and analytical procedures. Information is also given on general criteria such as color, taste, odor, nutrients, foaming and frothing materials, etc. as well as a classification of surface waters.

522 Stuart, C. H., 1970, Geopressures, in Supplement to the Proceedings of the Second Symposium on Abnormal Subsurface Pressure: Baton Rouge, Louisiana State University, 121 p.

This study describes the technology and scientific data necessary to design, drill, complete and produce geopressure wells for oil and gas. It emphasizes the Gulf of mexico Salt Basin, primarily in Louisiana and Mississippi. Some useful figures on location of some geopressure wells, geostatic gradient profiles, pressure depletion curves, Louisiana Gulf Coast sediment density and overburden gradient curve, and random selection of formation water salinities are given.

523 Summers, W. K., 1971, The annotated indexed bibliography of geothermal phenomena: Socorro, New Mexico Inst. Mining and Technology.

This book contains more than 14,000 references and provides more than 95 percent of the available references on thermal-water topics through December 31, 1969.

524 Sutterlin, A. M., 1974, Pollutants and the chemical senses of aquatic animals--perspective and review: Chemical Senses and Flavor, v. 1, p. 167-178.

A review covering the following subjects: importance of chemical communication in aquatic animals, possible types of interactions between pollutants and chemosensory systems resulting in disturbances in behavior patterns, methods used in studying some of these interactions, survey of the literature by pollution types, and conclusions. The review is not concerned with aspects of pollution-altered physiology or behavior that do not likely involve the chemical senses directly.

525 Swanberg, Chandler, A., 1975, Physical aspects of pollution related to geothermal energy development, in Second United Nations Symposium on the Development and Use of Geothermal Resources: San Francisco, California, 20-29 May 1975, p. 1435-1444.

Although geothermal energy is often called the "clean" form of energy, environmental problems do exist, and these problems must be defined, their deleterious effect evaluated, and suitable monitoring programs developed to insure environmentally compatible development. Venting of hot, geothermal byproducts into surface waters or the atmosphere may result in unacceptable environmental effects, particularly in "blind" geothermal areas which have not been subjected to natural thermal pollution from hot springs and geysers. Temporary holding ponds should be constructed to store geothermal gluids during drilling and testing, while reinjection is desirable during production. Remote sensing is effective in monitoring thermal pollution. Noise pollution can be a problem, particularly during drilling and testing. During production, however, noise levels can be reduced to acceptable levels. Land subsidence is a potential hazard, particularly in water dominated fields. Reinjection to stabilize reservoir pressures or the use of down hole heat exchangers minimize land subsidence. Prior to development, a level network should be established in and adjacent to the geothermal prospect and resurveyed periodically during production. Generation of earthquakes as a consequence of injecting fluids into active faults is well documented, and may constitute a problem, particularly for those geothermal fields which owe their existence to geothermal waters ascending along active faults. Development should be preceded by a program of microseismic monitoring to establish background seismicity and locate areas unsuitable for reinjection. A permanent seismic array is desirable but temporary monitoring, re-established periodically and of at least 8 weeks in duration due to the episodic nature of seismicity in some geothermal areas, is acceptable.

526 Swanson, R. K., Oetking, P., Osoba, J. S., and Hagens, R. C., 1976, Development of an assessment methodology for geopressured zones of the upper Gulf coast based on a study of abnormally pressured gas fields in South Texas, NTIS progress report, 1 Dec. 1975 - 29 Feb.1976: San Antonio, Texas, Southwest Research Inst., ERDA contract #E(11-1)-2687.

Twenty-four separate gas fields producing from geopressured sands have been identified in the south Texas area that includes Hidalgo, Cameron, Willacy and the lower half of Kenedy Counties. Of these, 20 are in Hidalgo County. Geological studies and detailed investigations of reservoir parameters in each of the fields have been accomplished. Two areas in particular are discussed in some detail in this paper: the Vicksburg trend on the west, reprented by McAllen Ranch field, and the South Central Frio-Vicksburg delta, including the McAllen-Pharr-Edinburg area. The depth of the geopressured temperature data within the fields, corrected to equilibrium values, yields a 300°F isogeothermal surface at depths of 10,500 to 14,000 feet over the study area. The most critical reservoir parameter was found to be the effective permeability in all the fields in the region. Permeability values ranged from .03 md. to 8.0 md., with average values over all the fields near 1.0 md. A permeability profile of McAllen-Pharr shows permeability there to be an inverse function of depth, with effective permeability values from 16 md. above the geopressured zone to 0.03 md. at 14,000 feet. The permeability reduction amounts to approximately one order of magnitude for each 2,000 feet of depth.

527 Swanson, R. K., Oetking, P., Osoba, J. S., and Hagens, R. C., 1976, Development of an assessment methodology for geopressured zones of the upper Gulf coast based on a study of abnormally pressured gas fields in South Texas, NTIS progress report, 1 March 1976-31 May 1976: San Antonio, Texas, Southwest Research Inst., ERDA contract #E(11-1)-2687.

During the fourth quarterly reporting period, a change in scope for this project was approved, extending the study area to include Brooks and the remainder of Kenedy and Live Oak Counties. An interim progress report covering that reporting period is presented. Effort during the quarter was directed toward (1) locating drill stem and production test results from geopressured formations, (2) determining formation parameters in an additionally large number of producing wells, and (3) searching production records for assessment of geopressured production in Brooks and Kenedy Counties. Several unsuccessful completion tests or geopressured water sands (attempted as gas completions) have been located, and these give insight into the problems of completing high-volume water wells in that zone. A successful fracture treatment in a geopressured gas well indicates a productivity increase equivalent to a two-fold improvement in permeability. Permeability calculations for a large number of geopressured and normally pressured gas wells throughout the study area have been completed. In no case has a producing Rio Grande Valley gas well deeper than 10,000 ft. been identified with effective permeability as great as 10 md. Preliminary investigation of Brooks County production has located geopressured production in seven gas fields and in North Kenedy County, an additional three.

528 Szescila, A. J., 1975, Techniques for gravel packing abnormally pressured unconsolidated reservoirs: Am. Soc. Mining Engineers, Paper #75-PET-37, September 21-25, 5 p.

Recent improvements in downhole completion tools and fluids, along with improvements in gravel packing methods, have made it possible to pack off and subsequently produce previously unmanageable geopressured zones. The techniques are field proven for both upper and lower zone packs and are compatible with any currently used carrying agent or workover fluid. The basic tool alignment would require only minor modifications of the conventional crossover tool assembly. The entire system has successfully functioned in fluids weighing 17.8 ppg.

529 Tanner, S. H., and Pullen, E. J., 1973, Hurricane barrier environmental planning in Texas: Am. Soc. Civil Engineers Proc., Jour. Waterways, Harbors and Coastal Eng. Div., v. 99, November, #WW4, paper 10171, p. 459-470.

Major environmental factors involved in planning coastal flood barrier systems along the Texas coast are presented. The intent is to show important environmental aspects to be considered in the planning of a protective system.

530 Teal, J. M., 1962, Energy flow in the salt marsh ecosystem of Georgia: Ecology, v. 43, no. 4, p. 614-624.

A review that attempts to pull together data from several studies on the area and construct a picture of the energy flow through the organisms of this marsh.

531 Texas Air Control Board, 1975, Annual Data Summary, Air Quality Control Regions #5, #7, #10: Texas Air Control Board.
The data presented in this report are the result of ambient air sampling which was conducted in the three coastal, industrial Air Quality Control Regions of Texas during 1975. Data is given for TSP, nitrate, sulfate, SO_2, total oxides, aldehyde and ammonia.

532 Texas Air Control Board, 1975, Annual data summary, Air Quality Control Regions #1, #2, #3, #4, #6, #8, #9, #11, and #12: Texas Air Control Board.
For Region 4 including Hidalgo, Cameron, Starr and Jim Hogg Counties, data is presented for TSP, nitrate, sulfate, SO_2, total oxides, aldehyde and ammonia.

533 Texas Air Control Board, 1975, Continuous monitoring network data summary: Texas Air Control Board.
Data from 13 continuous monitoring stations operated by Texas Air Control Board in major metropolitan areas of Texas. Some of these stations are located in Corpus Christi (Nueces Co.), Houston and Aldine (Harris Co.), Texas City (Galveston Co.,), Clute (Brazoria Co.), and Nederland and West Orange (Jefferson Co.). Air samples have been measured for ozone, CO, nonmethane hydrocarbons, hydrocarbons, methane, SO_2, H_2SO_4, total sulfur, NO_2, NO, wind speed, direction and ambient temperature.

534 Texas Coastal and Marine Council, 1977, Pictorial atlas of Texas coastal hazards: Austin, Texas Coastal and Marine Council.
This graphically summarizes several hazards of the Texas coast, particularly of the barrier islands, including hurricanes, subsidence and erosion.

535 Texas Organization for Endangered Species, 1975, TOES watch-list of endangered, threatened, and peripheral vertebrates of Texas. Pub., no. 1, 14 p.
The vertebrate list is cross-referenced with those of the Texas Parks and Wildlife Department and The U. S. Fish and Wildlife Service. Brief statements of distribution and preferred habitat in Texas and reasons for the assigned status are also given.

536 Texas Water Quality Board, 1972, A ready-reference on major Texas water pollution control legislation: Texas Water Quality Board Agency Pub. No. 71-01, 43 p.

Reference of the major pollution control laws with which the Texas Water Quality Board is concerned. The book includes background history on water pollution control in Texas. The acts covered are 1) Texas Water Quality Act, 2) County Solid Waste Control Act, 3) Solid Waste Disposal Act, 4) and the Disposal Well Act. Also, at the back of this booklet is a discussion of the State Matching Grants Program: Under Section 8 of the Federal Water Pollution Control Act (33 U. S. C. A. Sec. 1158), the Federal government can make grants to political subdivisions to assist them in defraying the cost of constructing waste treatment works.

537 Texas Water Quality Board, 1975, Texas water quality standards, Amended October 1, 1975: Austin, Texas Water Quality Board, 79 p.

The report consists of a general statement of the policies and rules set up to maintain the quality of water in the state including a classification of surface waters and description of standards. For each water basin, water uses deemed desirable and water quality criteria are tabulated.

538 Thatcher, T. O., Schneider, M. J., and Wolf, E. G., 1976, Bioassays on the combined effects of chlorine, heavy metals and temperature on fishes and food fish organisms. Part I. Effects of chlorine and temperature on juvenile Brook Trout (Salvelinus fontinalis): Bull. Envir. Contam. & Toxicol., v. 15, no. 1, p. 40-48.

Chlorine is commonly used in some 90% of the power plants in the U. S. as an antifouling agent. It is introduced as free chlorine from chloride gas or hypochlorite. However, due to the presence of various substances with which it readily combines, chloramines and/or other combined forms commonly appear in power plant effluents or immediately downstream from their point of entry into the receiving waters.

The combined effects of thermal alteration and chlorine exposures indicated synergism under these conditions. In chlorine effluent area where temperatures approach 20C, the concentration of total residual chlorine necessary to be acutely lethal to Brook Trout would be about 30% lower than in other areas (or times) where temperatures are in the 10-150 range. The effects of the previous temperature acclimation upon acute lethality of chlorine disappeared after about 2 days.

539 Thompson, C. R., 1976, Behavior of H_2S in the atmosphere and its effect on vegetation. University of California at Riverside, Statewide Air Pollution Research Center, National Technical Information Service Pub., no. PB-262 733/9WP, 20 p.

A study to determine the behavior and forms of hydrogen sulfide in the atmosphere and the effects of various concentrations of the gas on four species of plants.

540 Thompson, J. A. J. and Davis, J. C., 1976, Toxicity, uptake and survey studies of boron in the marine environment: Water Research, v. 10, p. 869-875.
The study attempts to determine the toxic and bioaccumulative dangers to aquatic life posed by borate discharge from a coastal British Columbia groundwood pulp mill. Bioassays were carried out on salmonids and oysters. Field studies were also conducted, and indicate a lack of evidence for tissue bioaccumulation. No hazards to salmonids or oysters at the present level of industrial discharge or boron was apparent from this work.

541 Thompson, T. W., and Gray, K. E., 1976, Rock mechanics aspects of geopressured and geothermal reservoirs: Subsurface and surface behavior, in Podio, A. L., ed., Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 3, Reservoir research and technology: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 85-100.
Controlled exploitation of a geopressured geothermal reservoir will depend upon the ability to predict the behavior of the reservoir rock under conditions of varying pore pressure and temperature together with the ability to assess the stability of the overlying rocks and the extent of any surface manifestations of the exploitation. Four major critical conditions are identified: change in fluid flow behavior caused by compaction, non-uniform deformation of overburden causing faulting, loss of stability of well holes, and surface subsidence. The mechanical effects of reservoir exploitation as functions of stress and temperature and examined and prediction models are assessed.

542 Thorhaug, A., 1976, Ecological study of the effects of power plants on benthic macroplant microcosms in subtropical and tropical estuaries: Annual progress report, 1975-76, Miami University, (NTIS: ORO-4493-3).
The major focus was to understand the function of the seagrass community and to relate this to the impact of energy related activities, most importantly, thermal effluent. In addition, the increased turbidity, current, siltation and heavy metals were factors at the Turkey Point site. Attempts were made to delineate the effect of heat in the laboratory to determine the upper thermal tolerance of the seagrass. It was shown to be quite close to the combined effect of all the pollutants in the field for Thalassia and the macroalgae. This would indicate that temperature is a very fundamental factor in the growth and survival of the seagrass community.

543 Tolivia, E., 1975, Corrosion of turbine materials in geothermal steam environments in Cerro Prieto, Mexico (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-44.

In starting to construct electric power generation plants utilizing geothermal steam, corrosion resistance of the turbine materials in the corrosive environments was investigated. From the test results, it was found that aeration of the steam and increase of flow velocity of the condensate not only enhance the corrosion rates of the materials to a remarkable extent but also change the corrosion behavior greatly.

In selecting materials, therefore, it is important to thoroughly investigate the corrosion characteristics of each material by analyzing the behavior and confirming deterioration of mechanical properties, in addition to evaluating corrision rates. In this sense, it is recommended to use the test data effectively in the following manner.

Carbon steel is usefully resistant and can be used for shell and piping in separated steam because its corrosion rate is low and follows parabolic law. In the condensate, however, design consideration must allow for corrosion or coating with epoxy resin because of high corrosion rates. As to 12Cr steel for blades, the deterioration of mechanical properties by corrosion, that is decrement of fatigue endurance limit, is more serious than the general corrosion rate. In view of this, design consideration should include the determination of allowable stress. Low alloy steels for rotor are almost equal to carbon steel in corrosion rate. Cr-Mo-V steel is more advantageous than Ni-Cr-Mo-V steel which deteriorates markedly in mechanical properties because of intergranular corrosion. Aluminum and deoxidized copper are unserviceable for heat exchanger tubes because of their poor corrosion resistance in the condensate. Titanium seems to be most suitable for it from our experience.

544 Touchet, B. A., Clark, H. L., Redlich, C. M., Roy, A. J., Griffis, B. J., Zaunbrecher, S. J., and Hallier, R. M., Department Agriculture, Soil Conserv. Service, August, 68 p. maps.

The Evangeline Parish soil survey contains a general soil map, a section describing the soils, and air photo coverage of the parish. Suitability of soils for several land uses is also given. Some of the land uses discussed are: agricultural, woodland and wildlife, and urban and recreational. Engineering characteristics are given as well as formation and classification of the soils. There is a section on the general nature of the parish.

545 Trent, L., Pullen, E. J., Adams, G., and Zamora, G., Jr., 1974, Catch per unit effort and mean total length of Brown Shrimp, Penaeus aztecus Ives, taken by trawl in the Galveston Bay

system, Texas, 1963-1967: National Marine Fisheries Service, Galveston, Texas, (NTIS: COM-74-11725/OST).

The report presents catches per unit effort and mean lengths for Brown Shrimp taken with a trawl and trawl cod end cover from the Galveston Bay system during 1963-67. Stations were located within three habitats--peripheral, open water, and channel--within each bay area of the system except West Bay.

546 Trent, L., Pullen, E. J., and Proctor, R., 1976, Abundance of macrocrustaceans in natural marsh and a marsh altered by dredging, bulkheading, and filling: Fish. Bull., v. 74, no. 1, p. 195-200.

Indices of abundance of macrocrustaceans during March-October 1969 in West Bay, Texas, were determined for day and night and statistically compared between 1) a natural marsh area, 2) upland and bayward canal areas of a housing development, and 3) an open bay area. Generally lower catches of each species in the open bay and upland canal areas compared with marsh and bayward canal areas were attributed to: 1) permanent loss of intertidal vegetation in the housing development; 2) low abundance of detrital material and benthic macroinvertebrates in the open bay and upland canal areas; and 3) eutrophic conditions in the upland canal area.

547 Truesdell A. H. and Fournier, R. O., 1975, Calculation of deep reservoir temperatures from chemistry of boiling hot springs of mixed origin (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume III-88.

Geothermometers based on the contents in hot springs of SiO_2 and of Na, K, and Ca are successful in indicating subsurface temperatures below 200-230°C. For higher temperatures, re-equilibration usually occurs during passage of the water to the surface. If hot and cold waters mix in the subsurface, indications of maximum temperatures may be preserved. Computations based on chemistry of mixed warm springs ($t=80°C$) have been described by Fournier and Truesdell (1974). A new method has been devised to calculate deep temperatures and hot-water fractions for mixed springs that issue at boiling temperatures.

In the following equations Cl is the chloride content; H_w, H_s, and H_{ws} are specific enthalpies at surface temperature of water, of steam, and of evaporation, respectively; H_{sil} is the enthalpy of liquid water at the temperature indicated by the silica geothermometer; and superscripts m, n, and c indicate mixed, nonmixed, and cold springs, respectively. H^h and X are the specific enthalpy and mass fraction of the hot component of the mixed water.

$$X = \frac{Cl^m H^n_{ws} (H^m_s - H^m_{sil}) + Cl^n H^m_{ws} (H^m_{sil} - H^c_w) - Cl^c H^n_{ws} H^m_{ws}}{Cl^n H^m_{ws} (H^n_s - H^c_w) - Cl^c H^n_{ws} H^m_{ws}}$$

$$H^h = \frac{H^m_{sil} - H^c_w}{X} + H^c_w$$

The method has successfully predicted observed deep temperatures for drilled geothermal systems in New Zealand and Chile.

548 Tucker, F. L., and Anderson, M. D., eds., 1976, Geothermal environmental seminar-'76: Geothermal Seminar, 390 North Forbes St., Lakeport, California 95453.

Thirty-five papers on geothermal environmental issues are included. Most concentrate on geothermal steam activities in northern California.

549 Turk, L. J., 1973, Leakage from solar evaporation ponds associated with sediment-brine interactions: Cleveland, Ohio, North Ohio Geol. Soc., 4th Salt Symposium Proc., Houston, Texas, April 8-12, v. 2, p. 403-406.

Leakage from solar evaporation ponds constructed in playa sediments may be increased dramatically by normal sediment-brine interactions. Certain fine-grained sediments, originally deposited in an environment less saline than the concentrated brine introduced into the evaporation ponds, are susceptible to subaqueous shrinkage which creates vertical fissures in the fine-grained sediments. Subaqueous shrinkage appears to occur during osmotic transfer of the fresher water from the sediments to the more saline brines in the pond, although syneresis may be an alternate mechanism for the dewatering. Development of such fissures in a solid which is expected to remain impermeable could create serious problems in other engineering works, for example: (1) clay liners in sanitary landfills producing saline leachate, (2) clay liners in brine-disposal or storage pits, or (3) earth-fill dams built to block saline springs (such as those proposed for tributaries to the upper Brazos River in Texas).

550 Turner, R. E. and Gosselink, J. G., 1975, A note on standing crops of Spartina alterniflora in Texas and Florida: Contr. Mar. Sci. Univ. Texas, v. 19, p. 113-118.

A late summer survey of eight Spartina alterniflora marshes in Texas and Florida was conducted. The live biomass is equivalent to or slightly greater than that found on the North Atlantic coast, but the dead biomass is considerably greater. Grass height--biomass relationships previously described for North Carolina and Rhode Island marshes are valid for the Gulf marshes. The slopes of the regression equations appear to increase with decreasing latitude and reflect changes in stem density and weight.

551 Underhill, G. K., 1975, Water requirements for geothermal energy utilization, in Gloyna, E. F., Woodson, H. H., and Drew, H. R., eds., Water management by the electric power industry: Univ. Texas, Austin, Water Resources Symposium no. 8, p. 242-249.
Geothermal resources are divided into four distinct types: (1) vapor-dominated convective, (2) liquid-dominated convective, (3) geothermal pressure, and (4) hot dry rocks. The characteristics and current uses of these four resource categories are described and compared with those for conventional thermal power plants for electricity generation. The impact of low thermal efficiencies of geothermal power plants is discussed in terms of water requirements.

552 Underhill, G. K., and others, 1976, Technology maturity and technology development, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 193-199.
Discussion of the state of knowledge of primary technical problems and how to gain the most significant information for solving these problems through the test site facility.

553 Underhill, G. K., and others, 1976, Brine disposal, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 183-191.
The purpose of this article is to discuss the accumulated evidence concerning disposal alternatives from the standpoint of technology, economics, and the environment. Subsurface and surface disposal are considered.

554 Underhill, G. K., and others, 1976, Preliminary conceptual design of commercial geopressured geothermal fuel plants, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization: Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 19-26.
Feasibility study for electric power generation utilizing geothermal resources focusing not only on the power plant, but also on fuel production and effluent disposal facilities. Preliminary conceptual design and costing activity of the fuel plants for three types of power generation facilities are outlined.

555 Underhill, G. K., and others, Preliminary conceptual design of commercial geopressured geothermal electricity generation plants, in Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 4, Surface technology and resource utilization:

Univ. Texas, Austin, Center for Energy Studies, February 23-25, p. 5-17.

An overall preliminary design study of a utilization facility to establish a baseline for technical, net energetic and economic assessment. Two conversion systems are considered: the flash steam and secondary working fluid cycles.

Brown and Root, Inc. studied the secondary working fluid plant, and Dow Chemical USA, Texas Division, studied the flash steam plant. Complete reports given by the two companies are contained in Appendix A and B in the back of the volume.

556 University of Oklahoma, 1970, A digest of the proceedings of the University of Oklahoma corrosion control course: Norman, Univ. Oklahoma, in cooperation with Natl. Assoc. Corrosion Engineers, 35 chapters.

Describes basic metallurgical considerations in corrosion control: application of cathodic protection, corrosion detection and control monitoring, protective coatings, corrosion inhibitors, oil field chemistry, scale treatments, chemical selection, etc.

557 University of Texas at Austin, 1968, Lessions in rotary drilling, Unit II, Lession 1: Making hole: Univ. Texas, Austin, Petroleum Ext. Service, 55 p.

The business of making hole is often a long series of compromises. To make the right decision, the driller and pusher have to be aware of the factors involved in drilling. The most significant of these are: (1) the geological section, (2) the capability of the rig, (3) the drilling fluid program, (4) the bit, (5) three critical factors: weight on the bit, rotary operation, the hydraulic factor.

558 University of Texas at Austin, 1968, Lessons in rotary drilling, Unit II, Lesson 2: Drilling mud: Univ. Texas, Austin, Petroleum Ext. Service, 98 p.

The drilling fluid is now recognized as one of the major factors involved in the success of the drilling operation. Speed, efficiency, safety and cost of drilling depend upon the performance of the drilling fluid used. The term "drilling fluid" properly includes gases as well as liquids and suspensions of liquids and solids in liquids. This lesson is limited to a discussion of suspensions of solids in a liquid, "muds", and of solids and a liquid in a second liquid, "emulsion muds". The cost of maintaining effective drilling mud is now necessarily a major item of the overall expense of drilling in many areas. The purpose of this lesson is to discuss the need for, the methods employed in, and the most economical maintenance of effective mud control.

559 University of Texas at Austin, 1968, Lessons in rotary drilling, Unit II, Lesson 4: Casing and cementing: Univ. Texas, Austin, Petroleum Ext. Service, 81 p.

Drilling for oil or gas involves two main objectives: (1) to bore a hole to the mineral accumulation and (2) to install a pipe from the reservoir to the surface. The pipe is called "casing" and has six important functions: (1) to prevent caving of the hole, (2) to prevent contamination of fresh water in upper sands by fluids from lower zones, (3) to exclude water from the producing formation, (4) to confine production to the well bore, (5) to provide a means of controlling well pressure, (6) to permit installation of artificial lift equipment for producing the well. The cost of casing is often the greatest single item of expense of a well. Selection of casing sizes, weights, grades and types of threaded connections for a given situation constitute an engineering and economic problem of considerable importance.

560 University of Texas at Austin, 1968, Lessons in rotary drilling, Unit II, Lesson 5: Testing and completing: Univ. Texas, Austin, Petroleum Ext. Service, 64 p.

From the very earliest days it was recognized that testing the porous zones to obtain samples of the fluid contents in a well was an essential part of the drilling job. The cable tool method of drilling made possible a continuous test prior to completing a well. The introduction of coring tools, drill stem testing, and electric logging changed the picture completely for rotary drilling by making drill stem testing and electric log analyses a practical field tool. The development of these tools has progressed to the point that formation evaluation can be accomplished without setting casing.

561 U. S. Army Corps of Engineers, 1971, Flood plain information, Chocolate Bayou, Brazoria County, Texas: Galveston, Texas, U. S. Army Engineer Dist., prepared for Brazoria County Conserv. and Reclamation Dist. No. 3, 35 p., maps.

This report relates to the flood situation along Chocolate Bayou in Brazoria County, Texas. Information is based on rainfall, runoff, historical and current flood heights and other technical data. The report contains maps, photographs, profiles and cross-sections which indicate the extent of flooding that can occur in the future.

562 U. S. Bureau of Land Management, 1975, Environmental studies, South Texas Outer Continental Shelf, 1975: Atlas and Integrated Summary: Prepared for the U.S.B.L.M. by the University of Texas, Texas A&M University, Rice University, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey, 303 p.

An environmental survey of the South Texas outer continental shelf concerned with hydrological, geological, biological, and chemical components of the shelf waters off the Texas Coast. The purpose of the study was to establish environmental baselines prior to oil and gas exploration in the waters of the Gulf of Mexico.

563 U. S. Department of Agriculture, 1974, General soil map, Iberia Parish, Louisiana: Alexandria, Louisiana, U. S. Dept. Agriculture, Soil Conserv. Service, 4-R-15, 681-A.

This general soil map shows the soil associations in Iberia Parish. A soil association is a landscape that has distinctive proportional patterns of soils. It normally consists of one or more major soils for which it is named, although several minor soils may be included.

Other information given on this map includes the description and use of soil associations, degree and kinds of limitations of the soils, classification by dominant land use capability, woodland site index (productivity of woodland), and potential for managed wetland wildlife habitat.

564 U. S. Department of Agriculture, 1976, Soil survey of Ascension Parish, Louisiana: U. S. Dept. Agriculture, Soil Conserv. Service, 54 p., maps.

The Ascension parish soil survey contains a general soil map, a section describing the soils and air photo coverage of the parish. Suitability of soils for several land uses is also given. Some of the land uses discussed are: agricultural, woodland and wildlife, and urban and recreational. Engineering characteristics are given as well as formation and classification of the soils. There is a section on the general nature of the parish.

565 U. S. Department of the Interior, 1973, Promulgation of leasing and operating regulations, Volume 1: in Final environmental statement for the geothermal leasing program, U. S. Dept. Interior, 421 p.

Volume 1 of this statement primarily relates to the promulgation of leasing and operating regulations for implementation of the geothermal leasing program as authorized by the Geothermal Steam Act of 1970 (30 USC 1001-1025 (1970)). The proposal is described in Chapter I. The national energy situation, geothermal energy resources and their potentials, a description of resource development and production phases, and a broad description of the environmental setting of the western states are included in Chapter II. The promulgation of leasing and operating regulations, the environmental impacts of the proposed action, mitigating measures, adverse impacts which cannot be avoided, the relationships between local short-term uses of man's environment and maintenance and enhancement of long-term productivity, and irreversible and irretrievable commitments of resources are discussed in detail in

Chapter III. Chapter IV includes discussions of alternatives for timing of actions, environmental provisions of regulations, leasing options, Federal and private exploration and development and electrical energy sources.

566 U. S. Department of the Interior, 1973, Leasing of federally owned geothermal resources for development in three California areas, Volume 2: in Final environmental statement for the geothermal leasing program, U. S. Dept. Interior, 511 p.

Volume 2 primarily covers the environmental evaluations for the three areas in California being considered for leasing (Clear Lake-Geysers, Mono Lake-Long Valley and Imperial Valley). These statements generally follow the same format as used in Volume 1 but with particular emphasis on environmental considerations pertaining to each area. General environmental information as contained in Volume I is not repeated in the individual statements unless such is needed to facilitate the description of actions, mitigating measures and environmental impacts. Also relative to the Draft Environmental Impact Statement, description of the consultation and coordination involved in the development of the proposal and the Draft Statement, and coordination in the review of the Draft Statement. Large scale maps of the three proposed lease areas are included.

567 U. S. Department of the Interior, 1973, Proposed geothermal leasing and operation regulations, Volume 3: in Final environmental statement for the geothermal leasing program, U. S. Dept. Interior, 686 p.

Volume 3 consists of copies of the various Federal Register publications of proposed leasing and operating regulations and related information as follows:

Appendix A - July 23, 1973 Proposed Regulations for Leasing on Public, Acquired and Withdrawn Lands; Revision of Proposed Rule (Including corrections of August 8, 1973)

Appendix B - July 23, 1973 Proposed Regulations for Operations on Public, Acquired and Withdrawn Lands and Geothermal Resources Unit Plan Regulations

Appendix A-B-Copies of comments received in response to the July 23, 1973 proposed regulations

Appendix C - November 29, 1972 proposed leasing regulations and summary of documents and Departmental responses

Appendix D - November 29, 1972 proposed operating regulations and summary of comments and Departmental responses

Appendix C-D-Copies of comments received in response to the November 29, 1972 proposed regulations

Appendix E - July 23, 1971 proposed leasing and operating regulations and May 3, 1972 supplement

Appendix F - Summary of comments and Departmental responses to the July 23, 1971 and May 3, 1972 propsed regulations

Appendix G - Vapor Dominated Hydrothermal Systems Compared with Hot-Water Systems

Appendix H - Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources.

568 U. S. Department of the Interior, 1973, Comments on draft impact statement and proposed regulations, Volume 4: in Final environmental statement for the geothermal leasing program, U. S. Dept. Interior, 720 p.

Volume 4 includes copies of all comments received on the Draft Environmental Impact Statement and the proposed regulations of July 23, 1971 and May 3, 1972. Also included in this volume are copies of transcripts of the hearings held at Reno, Nevada on November 9, 1971; Sacramento, California on November 11, 1971; and Portland, Oregon on November 12, 1971.

569 U. S. Department of the Interior, 1974, Proposed 1974 Outer Continental Shelf oil and gas general lease sale, offshore Louisiana, final environmental statement, Volume 1: U. S. Dept. Interior, Bureau of Land Management, 571 p.

The leasing of 215 tracts (952,592.48 acres) of OCS lands located off the Louisiana coast has been proposed. Drilling in these tracts will pose some degree of pollution risk to the environment and adjacent shoreline. Volume one, part one describes the steps to be taken to promote an orderly distribution of the OCS lands and development of offshore oil and gas production. Additional contract studies, research in progress, and proposed studies on the improvement of OCS management practices are described.

Part two reviews all pertinent environmental data. The geological setting, climate, and physical oceanography of the area are described. Biological information includes that of the Louisiana coastal zone and offshore environments. Economic and cultural resources as well as land use are also delineated.

Part three describes potential and unavoidable impacts on the natural environment, other Gulf of Mexico resources, air and water quality, land use patterns, the social order, and the economy.

570 U. S. Department of the Interior, 1974, Proposed 1974 Outer Continental Shelf oil and gas general lease sale, offshore Louisiana, final environmental statement, Volume 2: U. S. Dept. Interior, Bureau of Land Management, 394 p.

Volume 2 is a continuation of the impact statement for the proposed oil and gas lease sale of lands located off the Louisiana coasts as described in Volume 1. Part four discusses measures which will mitigate possible adverse impacts related to oil spills, offshore structures, and pipelines as well as other impact-producing activities associated with the oil and gas development resulting from this proposed sale.

Part five summarizes the unavoidable adverse environmental effects of oil and gas operations. This includes: effects on marine organisms, wetlands and beaches; deterioration of air and water quality; interference with commercial fishing and ship navigation; damage to historical and archeological sites; and interference with recreational activities and degradation of aesthetic values.

Part six discusses the relationship between local short-term use and maintenance and enhancement of long-term productivity.

Part seven describes the irreversible and irretrievable commitment of land, mineral, and fish and wildlife resources.

Part eight discusses two main alternatives to the proposed action: holding the sale in modified form and, withdrawal of the sale.

571 U. S. Department of the Interior, 1974, Proposed 1974 Outer Continental Shelf oil and gas general lease sale, offshore Louisiana, final environmental statement, Volume 3: U. S. Dept. Interior, Bureau of Land Management, 288 p.

Volume 3, part nine presents an account of the consultation and coordination processes involved in the preparation of the draft environmental statement (DES), and the steps leading to preparation of the final environmental statement (FES). All official review comments of the draft environmental statement are included, and where appropriate, the disposition of pertinent comments leading to preparation of the final environmental statement are indicated.

Part ten is a set of attachments which includes tabulated information, figures, sample forms, etc. supplementary to the main text. Relevant Federal regulations are summarized and a plat depicting the blocks proposed for leasing is included.

572 United States Department of the Interior, 1977, Guidelines for acquiring environmental baseline data on Federal geothermal leases: Menlo Park, California, U. S. Dept. Interior, The Geothermal Environment Advisory Panel.

These guidelines are developed to assist geothermal lessees and operators in complying with Federal Regulation 30 CFR 270. 34 (k) which states that a plan of operation shall include "A requirement for the collection of data concerning the existing air and water quality, noise, seismic, and land subsidence activities, and ecological system of the leased lands covering a period of at least one year prior to the submission of a plan for production."

The purpose of collecting environmental data is to provide a baseline representing selected physical, chemical and biological conditions prior to significant disturbance by lease operations against which later environmental data can be compared. This comparison will provide a basis for determining the net environmental change attributable to the operations on the leasehold at any subsequent time.

The purpose of these guidelines is to aid those involved in the exploration for geothermal resources in meeting the requirements for baseline data in a timely manner. Where unit operations are involved these guidelines should apply to the entire unit in the same way as to an individual leasehold. Their timing is designed to coordinate with the generalized scheme of phased operations outlined in orders issued or to be issued by the Supervisor, Conservation Division, USGS.

573 U. S. Environmental Protection Agency, 1973, Action for environmental quality: U. S. Govt. Printing Office Doc. 0-498-715.

The five most common air pollutants are: SO_2, NO_2, CO, particulates, and photochemical oxidents (hydrocarbons). National standards for these chemicals have been designed primarily to protect public health and to protect public welfare (e.g., clothes, buildings, metals, vegetation, crops, and animals). In addition, three hazardous air pollutants are regulated: asbestos, beryllium and mercury.

If a state does not submit a plan to implement national air quality standards set up by EPA, or if the plan is deemed inadequate, EPA can prepare and carry out an implementation plan for that state.

If anyone violates an approved implementation plan, EPA, after giving a state and the violator 30 days to act, can issue an order requiring compliance. A first violation is penalized $25,000 a day and 1 year imprisonment. Subsequent convictions are penalized $50,000 a day and 2 years imprisonment.

574 U. S. Environmental Protection Agency, 1976, Manual of water well construction practices: U. S. Environmental Protection Agency, Office of Water Supply, EPA-570/9-75-001, 156 p.

Comprehensive handbook containing generally accepted specifications for water well construction which serves to complement existing regulations and upgrades existing well construction techniques. Well construction techniques will vary with several major criteria: 1) intended use of water, 2) required capacity of well, 3) the nature of the producing zone, 4) the intended drilling method, 5) manner in which well construction will be paid for. A master key is given in which to find the section of the manual that applies to one's well construction purposes. This manual was designed to inform the lay person wanting to construct his own well, as well as consulting engineers and water well contractors.

575 U. S. Fish and Wildlife Service, 1976, Geothermal five year plan: U. S. Dept. Interior, U. S. Fish and Wildlife Service, Geothermal Proj., June 1976, 22 p.

The national objective of achieving energy self-sufficiency in the 1980's calls for rapid expansion in the development of geothermal energy. This development will result in a corresponding increase in impact on fish and wildlife resources. This five-year plan will provide guidance to the U.S. Fish and Wildlife Service in developing ecologically sound strategies to deal with geothermal development at the outset so that unnecessary environmental degradation can be prevented. Some of the objectives outlined in this plan are: 1) to improve federal legal, regulatory, and cooperative procedures in order to ensure that the consequences of geothermal impacts upon fish and wildlife are identified and provided for in the decision process; 2) to provide guidance and assistance to agencies responsible for geothermal exploration, leasing and development on Federal lands; 3) to provide biological and technical assistance to other Federal agencies, state and local governments and private industry; 4) to acquire new biological information to ensure that adverse geothermal resource development impacts on fish and wildlife populations are prevented and minimized and that areas under geothermal influence are enhanced; 5) to make national assessments of impacts of geothermal exploration and development on fish and wildlife resources; 6) to provide administrative and managerial support to the geothermal project. A chart projecting a summary schedule of effort by the U.S. Fish and Wildlife Service is included.

576 U.S. Fish and Wildlife Service, 1976, Geothermal handbook: U.S. Dept. Interior, U.S. Fish and Wildlife Service, Geothermal Proj. 1976, NP-21172, 193 p.

This handbook is designed for use by Federal and state fish and game departments, field biologists, industry, and the general public, to assist in meeting the need for scientific information incorporated in the planning and decision-making process so the ecological effects of geothermal energy development can be minimized. Chapter one, part one deals with national distribution and the nature of geothermal resources. A qualitative description is given on such topics as generation of electricity and other utilization techniques, exploration practices and drilling practices, and environmental matters in relation to development of the resource. There is also a glossary. Part two shows the current status of geothermal leasing and exploration in the western U.S. (not including the Gulf Coast section).

Chapter two, part one is the new cooperative geothermal leasing agreement adopted in June 1976, which formally includes the Fish and Wildlife service and is called "Memorandum of Understanding for the Geothermal Program". Part two explains the U.S. Fish and Wildlife Service interaction with geothermal development activity on state and private lands.

Chapter 3 presents environmental assessment procedures utilized during the general evolution of geothermal development on Federal lands for fish and wildlife resources. Table 28 charts a sequence of geothermal development and fish and wildlife assessment.

577 U.S. Geological Survey, 1975, Appendix: Discussion of data used in assessment of onshore geopressured-geothermal resources in the northern Gulf of Mexico basin, in Assessment of U.S. geothermal resources: Energy Resources Devel. Adm., U.S. Geol. Survey Circ. 726, p. 141-146.

The basis on which data presented in the various tables of ERDA/USGS Report 726 were determined, calculated, or assumed is discussed, and other untabulated data and equations used in the assessments presented are examined. Using the data for evaluating energy recovery plans other than those presented in the main text of the report is illustrated. Data on average conditions in subareas such as depth to top of geopressure, pressures, temperatures, and salinity, are analyzed. Data on properties of a conceptual reservoir include: thickness, porosity, and permeability of the sand aquifer; confining shale beds; hydraulic head and hydraulic conductivity; and transmissivity and storage coefficients. Density, methane content, kinematic viscosity, and specific heat of water are considered, and pipe friction and well-flow equations are detailed.

578 U.S. Geological Survey, 1975, Water resources data for Texas, water year, 1975, Vol. 3, Colorado River basin, Lavaca River basin, Guadalupe River basin, Nueces River basin, Rio Grande basin and intervening coastal basins: Austin, Texas, U.S. Geol. Survey, USGS/WRD/HD-76/025-3 vols. June, 523 p.

Surface-water data for the 1975 water year for Texas are presented in three volumes, appropriately identified as to content by river basins. Data in each volume consist of records of stage, discharge and water quality of streams and canals; and stage, contents, and water quality of lakes and reservoirs. Also included are crest-stage and flood-hydrograph partial-record stations, reconnaissance-partial-record stations, and low-flow partial-record stations. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements. Records for a few pertinent stations in bordering states are also included. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating state and Federal agencies in Texas.

579 U. S. Senate, 1975, Geothermal resources act of 1975, State of Texas: S.B. 685.

This act is related to the exploration, development, and production of geothermal energy and associated resources. Section 2 is a declaration of the policy of the State of Texas. Section 4 pertains to the authority and responsibilities of the Rail road Commission. They shall regulate the exploration, development and production of geothermal energy and associated resources on public and private land for the purpose of conservation of the resource and of protection of correlative rights. Section 5 refers to the authority and responsibilities of the General Land Office which is to provide for the orderly exploration of lands belonging to the Permanent School Fund of Texas, and to issue permits and charge reasonable fees for such permits. The School Land board on direction of the Commissioner of the General Land Office may set terms and lease any lands belonging to the Permanent School Fund of Texas and grant permits and leases to state and Federal institutions, organizations, or groups desiring to do exploratory or experimental research of geothermal energy and associated resource potentials on lands belonging to the Permanent School Fund of Texas.

580 Urban, T. C., Jamieson, I. M., Diment, W. H., and Sass, J. H., 1975, Heat flow at the Geysers, California (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, III-89.

Temperature profiles in three cased holes close to thermal equilibrium have been obtained over a known part of the Geysers steam field in Sec. 14, T11N, R9W, MDBM and in one hole near Cloverdale some 13 km to the west. The linearity of the temperature-depth curves to the maximum depths examined (200-1000 m) suggests conductive transport of heat. Moreover, linear extrapolation of these temperatures to the depth of "first steam" (where known) yields a temperature close to that of the steam reservoir, which is generally regarded as about 240°C. This suggests that heat transport is mainly conductive through the whole interval between the surface and the reservoir, at least at this locality. It also suggests that the reservoir temperature has remained relatively constant for tens of thousands of years.

On the basis of thermal conductivity measurements from the Cloverdate core samples and from outcrops, we assign a conductivity of 7×10^{-3} cal/cm/sec/°C to all the holes. This yields heat flows of 3 HFU (10^{-6} cal/cm^2/sec) for Cloverdale and 9, 11, 12 HFU for the three holes in section 14.

Elementary calculations show that the conductive heat flux in and about the field is very small relative to that of present steam production but that energy stored above ambient is large with respect to steam production.

581 Ushijima, K., 1975, A thermometer for geothermal thermometry in a geothermal well (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-46.
Geothermal thermometry in a geothermal well is carried out to detect the channels through which geothermal fluids enter a borehole and to determine the temperature distribution in geothermal fluids. The location of the cement tops behind casings is also determined by temperature measurement in well. In order to treat the temperature variation due to drilling operations or other non-stationary processes analytically, it is necessary to obtain reliable temperature logs.

An accurate and inexpensive thermometer using a platinum wire resistor as sensing probe has been developed for increasing requirements for reliable temperature logs. The thermometer was designed to have such specifications as measuring range up to 300°C and waterproof up to 150 bar. The laboratory test of the thermometer confirmed that it worked satisfactorily up to temperature of 213°C and external pressure of water less than 90 bar. In the field test in Denken borehole at Otake geothermal area, Oita prefecture, Japan, performance of the thermometer was checked with maximum temperature of 176°C and maximum depth of 340 m.

The present paper explains in detail the structure of the equipment, temperature calibration, pressure test, determination of time constant and results of field test.

582 Van Sickle, V.R., Barrett, B.B., Ford, T.B. and Gulick, L.J., 1976, Barataria Basin: Salinity changes and oyster distribution: Louisiana Wildlife and Fisheries Commission Pub., no. 20, 22 p.
Considers the biology, production and distribution of the American Oyster in the Barataria Basin as correlated with environmental factors such as spatfall, growth, reproduction, and mortality. Mortalities resulting from predation and disease are associated with increased levels of salinity and temperature. Distribution is directly related to salinity. This paper explains the interrelationships that exist between salinity and other environmental variables.

Increasing salinities in the Barataria area have allowed the oyster populations to move further inland (spatfall occurs further inland). This inland movement could be detrimental, as encroaching levels of pollution intrude seaward into areas of current and future oyster production.

583 Vanston, J.H., and others, 1976, Proceedings, Second Geopressured Geothermal Energy Conference, Vol. 5, Legal, institutional and environmental: Univ. Texas, Austin, Center for Energy Studies, February 23-25.

Legal, environmental, socioeconomic, demographic, and political factors in the development of geopressured geothermal resources off the U.S. Gulf Coast are analyzed. Legal issues considered include resource definition, ownership, taxation, and multistate reservoirs. The physical model of the geopressured geothermal resource is compared with the model articulated in statutes and case law. Few statutes include all types of geothermal resource in definition. Geothermal fluid disposal, particularly of hot saline water, potential land subsidence and possible activation of faults are major environmental concerns. Baseline social, political, and demographic data are presented, and the local socioeconomic impacts of drilling, development and production are assessed. Individual parts of this volume are cited under separate authors.

584 Van Voris, P., 1976, Ecological stability: An ecosystem perspective. Classical and Current thoughts: Review of selected literature: Oak Ridge National Laboratory, National Technical Information Service Publ., no. ORNL/TM-5517, 40 p.

This review of selected literature points out the problems inherent in relying on either static measures as a measure of complexity to arbitrarily rank the relative stabilities of ecosystems, or the dynamic approach of analyzing the mathematical stability of linear or nonlinear models. The research direction emphasized is that of development of new measures of ecosystem complexity based on ecosystem level characteristics and relating these measures of complexity to an a priori defined ecosystem stability.

585 Villa, F. P., 1975, Geothermal plants in Italy: their evolution and problems (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-25.

The use of geothermal steam for power production started in Italy in 1894 in addition to the use of its heat for other purposes.

The paper describes main plants in operation today.

Recently it was decided to drive bigger gas compressors directly by main turbogenerators including units of 30 MW.

Problems including those for plants with wet steam are listed and discussed.

586 Wahl, E.F. and Yen, I-K., 1975, Calcite and silica deposition from geothermal brines (abs): in Second United Nations Symposium on the Development and Use of Geothermal resources, San Fran-

cisco, California, 20-29 May 1975, Abstract volume, VI-47.
The scaling characteristics of synthetic and East Mesa Well 6-1 geothermal brines were studied using a specially constructed test unit. The test unit was capable of simulating a variety of process conditions including flashing of the brine and separation of the vapors from the liquid prior to the scaling test section. Heated, cooled and zero heat flux probes were used.

A mathematical model of the form $K(1-e^{-t/T})$ was derived for the synthetic brines experiments. The experimental data were correlated by this model and the value of K/T increases from 0.03 to 1 for Reynolds numbers increasing from 20,000 to 40,000, decreases from 2.5 to 0.6 as silica sand additive is increased from 0 to 5 grams per liter, and increases from 0.1 to 2.5 as total CO_2 expressed as HCO_3 concentration is increased from 0 to 500 mg/liter.

Experiments at the East Mesa Test Site using brine from Well 6-1 showed that the predominant scale was calcite. A mixture of iron and silica scale was the next most significant scale. No scale formed until the brine was allowed to flash. The location of scaling could be controlled by the separator operation. Relative to flashing, scaling was independent of heat flux.

587 Wallace, W.E., 1969, Water production from abnormally pressured gas reservoirs in south Louisiana: Jour. Petroleum Technology, v. 21, no. 8, p. 969-983.

This paper presents an investigation of reservoirs having sandstone porosity surrounded by shale; containing gas, condensate and salt water; and all under conditions of abnormal hydrostatic pressure. Examples are taken from fields in South Louisiana of ages ranging from Oligocene (Frio) to Miocene, and that produce gas, condensate, and varying amounts of water (from 0-100% or only water influx). Case histories of these fields are given to illustrate mechanisms of abnormal pressures, shale compaction, and water influx.

588 Walter, R.A., Bloomster, C.M., and Wise, S.E., 1976, Geothermal power plants: Richland, Washington, Battelle Pacific Northwest Labs., ERDA Contract #AT (45-1)-1830.

A computer program has been constructed at Batelle-Northwest Laboratories to analytically model four different geothermal power plants. GEOCOST, a simulation model which calculates the cost of generating electricity from geothermal energy, is composed of two principal sections: a reservoir model which simulates the exploration, development, and operation of a geothermal reservoir, and a power plant model which simulates the design, construction, and operation of the power plant. The power plant models include the flashed steam plant, binary fluid cycle plant, total flow plant, and the geopressured plant. This computer model can be used to predict the optimum power plant type and operating conditions for use with a particular geothermal resource. Using the overall model, sensitivity analyses can be performed to determine the relative effect of different economic parameters, assumptions, and uncertainties on the cost of generating electricity.

589 Wang, W.C., Yung, Y.L., Lacis, A.A., Mo., T., and Hansen, J.E., 1976, Greenhouse effect due to man-made perturbations of trace gases: Science, v. 194, no. 4266, p. 685-690.

Discussion of the nature and climatic implications of possible changes in the concentrations of N_2O, CH_4, NH_3, HNO_3 and other trace gases because of their role in transmitting thermal radiation from the earth's surface and lower atmosphere.

590 Ward, G.H., Jr. and Espey, W.H., Jr., 1971, Estuarine modeling: An Assessment. Capabilities and limitations for resource management and pollution control: TRACOR report to the Water Quality Office of the Environmental Protection Agency, 497 p.

This report constitutes a technical review and critical appraisal of present techniques of water quality modeling as applied to estuaries. Various aspects of estuarine modeling are treated by a selection of scientists and engineers eminent in the field, and these essays are supplemented by discussion from a technical conference held during the course of the report's preparation. Topics discussed include one-, two-, and three-dimensional mathematical models for estuarine hydrodynamics, water quality models of chemical and biological constituents including D.O., BOD, nitrogen forms, phytoplankton and general coupled reactants, models of estuarine temperature structure with special attention given the modeling of thermal discharges, and the principles and applicability of physical models in estuarine analysis.

591 Warner, D.L., 1975, Monitoring disposal-well systems: Santa Barbara, California, General Electric Company, and Las Vegas, Nevada, TEMPO Environmental Monitoring and Support Lab., Monitoring Systems Research and Development Div. Rept. #GE74TMP45, July, 113 p.

The Environmental Protection Agency is required, under P.L. 92-500, "The Federal Water Pollution Control Act Amendments of 1972", to establish a system for the surveillance of the quality of the nation's surface and ground waters. Enactment of P.L. 93-523, "The Safe Drinking Water Act", further requires that state programs in order to be approved, shall include monitoring programs to prevent underground injection which endangers drinking water sources. This report provides information concerning the data needed for monitoring the subsurface injection of waste-water through cased disposal wells and discusses the methods and tools available for obtaining the data. The procedures for using the data for predicting the response of the receiving aquifer to injection are then outlined. Surveillance of operating disposal wells is reviewed. Numerous examples are given throughout the text.

592 Warner, R. W., 1973, Water pollution: Fresh water macroinvertebrates: Jour. Water Pollution Control Fed., v. 45, no. 6, p. 1231-1237.
A literature review on the use of fresh water macroinvertebrates to determine the effects of water pollution. Included are reviews of the literature on: inorganic wastes, organic wastes, pesticides, radiation, physical environmental alterations, secondary production, periodicity and drift, distribution and habitat requirements, and techniques.

593 Wehlage, E. F., 1975, Social implication may arise with future geothermal usage (abs): Second United Nations Symposium on the Development and Use of Geothermal in Resources, San Francisco, California, May 20-29 1975, Abstract volume, XI-14.
The fullest implication of geothermal heat's effect on society--when it is fully and effectively used--is not being given adequate attention. Geothermal development, especially for electrical generation, is becoming socially impacted in the U. S. A. Governmental influences evolve.

Its effect on the social structure is not only economic in an energy dilemma, but people as a society will be increasingly involved. Geothermal's nature is that with non-electric utilization (required for the greatest benefit), population and industry will be forced to move causing social pressuries in an unknown degree. Better social preparation is mandatory. The fullest use of geothermal heat may dictate drastic reorganization.

594 Wehlage, E. F., 1975, Freezing with terrestrial heat--or geothermal cooling (abs): in: Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, XI-11.
The creation of refrigeration effect from terrestrial heat (or more simply, "geothermal cooling"), while recognized, is not fully understood below 0°C to a practical limit of-60°C in food preservation, freeze-drying, and process work. The author reviewed potential geothermal systems in previous papers, including designs applying lithium-bromide-water as low as +4°C. This paper outlines by-passing electrical power generation stages when using a water-ammonia binary couple for temperature depressing in the zero to minus 60°C range. Parameters and problems discussed include: (1) evaporator temperature, (2) geothermal fluid heat level, (3) heat rejection temperatures, (4) "cascading" or energy--in and out, and (5)"boot-strapping" with fossil fuel auxiliaries.

595 Wehlage, E. F., 1976, The basics of applied geothermal engineering: West Covina, California, Geothermal Inf. Services Pub. 211 p.
This is a comprehensive introduction to applied geothermal engineering which has a single purpose: To provide a basic background of history and practice for people whose work involves geothermal heat but who may lack a specialized interest in engineering, geology, or the earth sciences related to terrestrial heat formation.

While specific and complete answers for all newly evolving geothermal technology questions cannot be fully covered, the text does offer a basic understanding of the problems to be encountered and some of the various solutions which may be available.

Some topics covered include the historical background of geothermal utilization, basic physical properties of steam, consideration of geothermal refreigeration and other secondary applications of geothermal energy.

Numerous photographs and diagrams supplement the written material in an illustrated review of what rests behind engineering needs for applied geothermal energy from earthly heat.

596 Wentz, W. A., Smith, R. L., and Kadlec, J. A., 1974, State-of-the-art survey and evaluation of marsh plant establishment techniques: Induced and natural. Volume II, A selected annotated bibliography on aquatic and marsh plants and their management: University of Michigan report to the U. S. Army Engineering Research Center, Fort Belvoir, Virginia, Report no. D-74-9, 209 p.
The purpose of this bibliography is to make available an annotated listing of references which were not cited in Volume I. Although the bibliography does not represent an exhaustive review of the literature, it does provide an extensive survey of the pertinent references on the ecology and management of aquatic and marsh plants. The references selected for the bibliography emphasize studies useful to researchers and managers. In accordance with the focus of Volume I, this volume concentrates on coastal, Great Lakes, and riverine marshes.

597 White, D. C., and Williams, D. L., 1975, Summary and conclusions: Assessment of geothermal resources of the United States--1975: USGS/ERDA Rept., U. S. Geol. Survey Circ. 726, p. 147-156.
The writer concludes that the geopressured fluids of the Gulf Coast have a huge geothermal potential. Much of this resource is probably paramarginal under present conditions, but some part is probably recoverable now from areas where the environmental impact is low. Other types of geothermal sources and their potential are also summarized. Disregarding cost, the total magnitude of geothermal resources that can be recovered by present and near-current technology is very large. The resource base and recoverability are examined.

598 Whitehurst, C.A., Kinney, R.A. and McPhate, A.J., 1974, A parametric study of water resource variables in a delta region of South Louisiana - Bayou LaFourche. Volume I. Technical discussion, Volume II. Appendices: Louisiana State Univ., Baton Rouge. Division of Engineering Research. (NTIS: PB-232 521/5).

Bayou LaFourche is the only fresh water source for the population (150,000) of several parishes in South Louisiana. It is presently under stress due to increased navigation, flooding, and industrial use. The bayou was modeled both hydrologically and from a water quality viewpoint. Tides and winds proved to be the most influential factors in the movement of the stream, and these factors, coupled with the complexity of the canal-bayou-estuary network, generated a unique modeling effort. Baseline biological indices were established for the bayou. An attempt to correlate all measured parameters including chemical, biological and hydrological, was made. Water needs through 1980 were predicted.

599 Whitman, H.M., and Kilburn, C., 1963, Ground water conditions in southwestern Louisiana 1961-62, with a discussion of the Chicot aquifer in the coastal area: Louisiana Dept. Conserv., Louisiana Geol. Survey and Dept. Public Works, Water Resources Pamph. no. 12.

Presents information on ground water withdrawals, and the geology of the Chicot aquifer in coastal southwestern Louisiana. Effects of withdrawals are shown by 1) tabulated water-level data, 2) a contour map showing the elevation of the water surface, 3) three hydrographs, and 4) by comparing the weighted-average water level for the spring of 1962 with that of 1961.

600 Williams, D. L., 1975, Evaluation of submarine geothermal resources (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, I-40.

Approximately 20 percent of the Earth's heat loss (or 2×10^{12} cal/sec) is released through 1 percent of the Earth's surface area and takes the form of hydrothermal discharge from young (Pleistocene or younger) rocks adjacent to active sea-floor spreading centers and submarine volcanic areas. This amount is roughly equivalent to man's present gross energy consumption rate. This heat is released along 55,000 km of spreading ocean ridge in the form of heated sea water at depths 2 to 3 km below sea level.

Submarine geothermal resources tend to be ignored because they occur in a remote, hostile, high-pressure and corrosive environment. A similar opinion of offshore reservoirs was held by the early petroleum industry. Yet, much of the Earth's petroleum is produced today through the sea floor.

Although most of the heat escapes far from land, there are some notable exceptions. In the Gulf of California, Red Sea, and along the Reykjanes ridge south of Iceland, thermal gradients in the bottom sediments exceed 1° C/m, suggesting the existence of high-temperature water at very shallow depths. There is geochemical evidence that reservoir temperatures exceed 300°C and geophysical evidence that reservoirs may be 3-5 km thick. In the coastal areas of the Gulf of California, where electricity and fresh water are at a premium, this potentially enormous resource lies within sight of land. However, since none of these reservoirs have been drilled and little else is known of their physical characteristics, the very existence of an exploitable resource remains an open question.

601 Willis, E.H., 1976, ERDA's geothermal R and D program: 3rd Energy Technology Conf., Washington, D.C., March 29-31, p. 115-119.

ERDA's geothermal energy program aims to: reduce resource uncertainties and increase reservoir predictability, develop identified hydrothermal resources and help establish an industry base, and help industry develop technology to exploit geopressured and hot dry rock resources. The nation's geothermal resources, which are described, are large enough to warrant an intensive development program. ERDA geothermal development strategies are discussed.

602 Wilson, J.S., Shepherd, B.P., and Kaufman, S., 1975, Economic analysis of the use of Texas geopressured geothermal resources for the production of electrical power, in Dorfman, M.H., and Deller, R.W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 267-279.

This study undertook to calculate the production capabilities of two actual geopressured geothermal reservoirs, both located in South Texas, and to calculate the economics of producing power from these reservoirs. Conventional flash systems and secondary fluid systems were designed, flows calculated, and power costs determined for both systems.

603 Wilson, J.S., 1975, An analysis of the potential use of geothermal energy for power generation (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VI-48.

The deep geopressured hot brines found in the geosynclinal basin of the northern Gulf of Mexico are shown to be a potential source of geothermal energy for the generation of electric power. Two typical reservoirs were selected for production calculations. Results indicated water yields sufficient to power a 25-megawatt plant for 20 years in one reservoir and a 60-megawatt plant in a second. Reservoir sizes were based on the assumption that known sands are bounded by existing fault systems. Sand thickness, permeability, and porosity were taken from oil well data. Water temperature of 196°C at a depth of 4,500 to 5,600 meters was obtained from well longs in the area. A flow rate of 51,000 barrels of brine per day was assumed from a 17.8-cm. diameter well casing.

Economics of power production are calcuated using an isobutane secondary cycle, a single-stage flash system, and a dual-stage flash. Maximum power was obtained from the secondary cycle, but a dual flash gave 97% equivalent power at a cost of 26.8 mills per kwh compared to 33.3 mills per kwh for the dual cycle. Both calculations assumed credit for 0.85 cubic meters of natural gas per barrel of water since considerable evidence exists that these waters will be saturated with natural gas at their existing pressures and temperatures.

It is concluded that a considerable potential, possibly as high as 40,000 megawatts of power, exists along the Texas Gulf Coast. However, the high risk-reward ratio precludes private development. The size of the potential and the interest to the public appear to justify expenditure of government funds to investigate this resource. A five year development program is proposed, culminating in a 10-megawatt demonstration plant.

604 Windom, H. L., 1972, Environmental aspects of dredging in estuaries: ASCE Jour. Waterways, Harbors, Coastal Engineering Division 98 (ww4), Paper no. 9342, p. 475-487.

Salt marsh estuarine environments along the Intracoastal Waterway of the southeastern Atlantic coast were studied to determine the environmental effects of dredging in these areas. The study dealt with chemical response of salt marsh sediments to the deposition of dredged materials and with the water quality response to dredging and deposition of sediments in a salt marsh estuarine environment.

605 Winner, R. W., 1976, Toxicity of copper to Daphnids in reconstituted and natural waters: Miami University, Oxford, Ohio. Environmental Research Laboratory, Duluth, Minn., 81 p. (NTIS: PB-252 915/4ST).

The toxicity of copper was compared for Daphnia magna cultured in reconstituted versus pond water and fed on trout-pellet versus vitamin-enriched, algal foods. Effects of a chronic copper stress were highly variable when animals were tested in reconstituted waters. This variability is thought to be due to variability in the quality of the distilled water matrix. The vitamin-enriched algal food was found to be superior to the trout-granule food in culturing D. magna. Control animals lived much longer and test animals were less sensitive to a chronic copper stress. The acute and chronic toxicity of copper was also compared for four species of Daphnia. When tested in pond water and fed vitamin-enriched algae, the two largest species (*D. magna* and *D. pulex*) were significantly less sensitive to an acute copper stress than the two smallest species (*D. parvula* and *D. ambigua*). There was, however, no significant difference in sensitivity to a chronic copper stress when reduced longevity was used as the index. Application factors for the four species varied from 0.47 to 0.62 and were not significantly different.

606 Wohlschlag, D.E., 1976, Analysis of freshwater inflow effects on metabolic stresses of fish in Corpus Christi, San Antonio, and Matagorda Bays: Final report to the Texas Water Development Board for TWDB contract no. 14-60020 (IAC-7677-0632), 100 p.

The purpose of this study is to evaluate stresses related to freshwater influxes on the coastal subadult and adult Spotted Seatrout, which is highly valued for food and recreation. The investigation involved rationales for: 1) investigation of freshwater inflow effects on South Texas estuaries and bays; 2) utilization of fish as indicators for optimal effects of these inflows; and 3) the use of metabolic and swimming rate techniques for the assessment of inflow effects independently of fishery and pollution effects.

607 Wohlschlag, D.E., and Cameron, J.N., 1976, Assessment of a low level stress on the respiratory metabolism of the Pinfish (*Lagodon rhomboides*): Contr. Mar. Sci. Univ. Texas, v. 12, p. 160-171.

Multiple regression analysis of Pinfish respiration as related to weight, temperature and swimming velocity in "slightly" polluted water resulted in a depression of respiratory metabolism. Metabolic depression is discussed in terms of "winter kill" in larger fish. Also included are considerations of artificially increased winter temperatures in terms of high maintenance requirements of fish presented with stress such as those induced by pollution. Includes considerations of reduced growth rates on populations.

608 Wood, C.E., 1967, Physioecology of the Grass Shrimp, *Palaemonetes Pugio*, in the Galveston Bay estuarine system: Contr. Mar. Sci. Univ. Texas, V. 12, p. 54-79.

Seasonal distribution, growth rate and reproductive potential of grass shrimp are considered as affected by temperature and salinity, both in the field and in laboratory studies.

609 Wood, L.A., 1974, Use of underground space for waste storage through injection wells: Extraction of Minerals and Energy: Today's Dilemmas. International Workshop on Environmental Problems of the Extraction Industries, Dayton, Ohio, June 10-13, 1973, Ann Arbor Science Pub. Inc., Paper no. 16, p. 193-202.

Properly sited, constructed, and operated, waste-injection wells can provide safe storage of industrial wastes. Aquifer plugging by particles in waste, or by chemical reactions among waste, rock, and formation fluid, or by growth of bacteria, can prevent the operation of an injection well. Environmental problems may result from injection wastes. The waste displaces brine that may flow to the surface or to fresh aquifers through abandoned test holes or old wells that have been destroyed by corrosion. Also, excessive injection pressure may fracture confining beds and permit waste to flow into other aquifers. Geological exploration, hydrologic testing and evaluation, and engineering design and construction will reduce both the possibility of well failure and the chances of pollution. The use of waste-injection wells is a much smaller threat to the environment and the pollution of ground water than is the improper surface disposal of waste, or careless handling and storage of chemicals, accidental spills of petroleum products and other liquids, and many other activities unrelated to waste storage.

610 Woodward-Lundgren and Associates, 1974, Detection and Evaluation of Differential Surface Displacement in the Texas Gulf Coastal Region: Oakland, California, 60 p.
This report undertakes the study of the causes of differential surface displacement and determines which and to what degree they are significant to sites on the Texas Gulf Coast. Reliable techniques are shown to exist for the detection of planes of differential surface displacement and methods are available to evaluate the movement potential of planes of differential surface displacement. The report includes a study of case histories.

611 Young, A., and Low, P.F., 1965, Osmosis in argillaceous rocks: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1004-1008.
Osmotic flow of water through samples of shale and siltstone is demonstrated in laboratory experiments on cores from the Lower Cretaceous Viking Formation in Canada. The pressures which were developed by constraining water movements were far less than theoretical osmotic pressures associated with salinity differences causing the water to move. This discrepancy is explained by assuming that: 1) the samples probably contained micro-cracks associated with coring and removal from depth, and 2) some of the pores in the rock samples wer probably too large and too weakly charged to restrict salt movement.

612 Young, F.S., 1975, Well-information systems as applied to geopressured reservoir description, in Dorfman, M.H., and Deller, R.W., eds., Proceedings, First Geopressured Geothermal Energy Conference: Univ. Texas, Austin, Center for Energy Studies, p. 193-204.

Summary of information systems developed to monitor drilling operations and to provide sufficient forewarning to ensure operational safety of a geopressured well. Some sample well longs are shown.

613 Zancani, C., 1975, Thirty years experience synthesis in selecting thermal cycle for geothermal power plants (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume VII-28.

The writer reviews here the various thermal cycles which have been or are being adopted to exploit geothermal power.

Before 1946, the only geothermal fields exploited were the Italian ones. The electric power production was coupled with the production of boric acid, concentrating solutions which had a content of 0.0002 of H_3BO_3. The secondary steam, free from noncondensable gases, was sent to the turbine.

These cycles reduced the problems connected with the elimination of the large quantity of noncondensable gases and corrosion.

The author examines flow diagrams, efficiencies and limits for possible economical introduction in modern plants.

After 1946 the cycles with direct turbine inlet of the geothermal steam were adopted, thanks to the new corrosion-resistant materials and to much progress achieved in construction of compressors for noncondensable gases.

The author examines the wet and superheated steam cycles and outlines the problems which are most likely to be encountered in the design of future power plants exploiting natural or artificial geothermal fields.

614 Zancani, C., 1975, Problems faced by the engineer at Mexicali geothermal power plant (abs): in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, Abstract volume, VII-29.

The author describes the contribution given by ELC-Electro consultants to the development of the Cerro Prieto Geothermal Power Plant project at Mexicali, mainly in relation to the general arrangement and the design of cooling water channels and piping and relevant towers.

He reviews the various difficulties originating from the peculiarity of the climate, in particular, for the cooling towers and the location of the power house which is not in a barycentric position with respect to the location of the producing wells.

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1 2 10 11 21 22 23 26 30 40 51 54
57 59 69 70 73 76 86 90 93 94 98 102
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138 146 165 173 174 182 189 190 210 214 215 216
217 219 223 224 237 250 255 257 267 269 275 276
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319 320 321 323 325 326 328 361 362 366 370 380
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431 438 442 469 481 485 491 497 501 505 508 524
530 540 550 569 570 571 584 590 592 600 604 605

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6 36 41 42 57 61 69 70 72 89 90 92
94 97 99 108 110 121 123 125 126 127 133 146
147 148 160 164 178 188 198 200 201 205 214 215
219 220 226 236 249 250 264 281 282 283 284 288
290 295 296 308 311 313 317 319 320 321 323 325
326 328 334 335 336 339 346 347 348 349 350 354
355 356 357 358 360 362 366 367 375 390 397 404
405 411 412 413 426 429 431 454 466 467 468 471
476 479 494 496 498 508 521 534 535 544 550 563
564 569 570 571 582 584 587 590 592 598 599 605

3. TEXAS, WILLACY-CAMERON FAIRWAY

40 66 68 71 72 82 90 94 123 127 165 189
190 215 216 218 219 220 227 234 236 244 260 264
281 290 296 311 319 320 325 326 328 362 363 397
404 405 447 476 507 532 535 584 605

4. TEXAS, KENEDY FAIRWAY

40 72 82 90 94 123 165 189 190 215 216 218
219 220 227 236 260 264 281 290 296 311 319 320
325 326 328 362 363 366 397 404 405 447 476 486
507 535 584 605

5. TEXAS, NUECES-CORPUS CHRISTI FAIRWAYS

14 16 17 20 25 36 40 43 56 57 58 65
67 68 69 70 72 81 82 90 93 105 108 109
110 111 112 113 115 116 121 122 123 127 129 131
146 151 152 165 170 171 189 190 195 210 214 215
216 218 219 220 227 233 236 238 239 240 241 242
243 250 251 252 254 257 260 264 278 281 285 288
290 295 296 308 311 313 317 319 320 321 323 325
326 328 362 363 366 367 377 383 390 391 397 404
405 410 411 412 426 443 447 476 490 492 508 534
535 550 584 590 592 605 606 607

6. TEXAS, MATAGORDA FAIRWAYS

4 17 20 36 40 43 56 57 58 68 69 70
72 81 82 84 90 93 94 105 108 110 111 112
113 115 116 121 122 123 127 129 131 137 146 151
165 170 171 189 190 210 214 215 216 218 219 220
222 227 236 243 250 251 252 257 260 262 264 278
281 285 288 290 295 296 308 311 313 317 319 320
321 323 325 326 328 359 362 363 366 367 376 377
390 391 397 404 405 411 412 426 447 476 508 534
535 550 584 590 592 605 606

7. TEXAS, BRAZORIA FAIRWAY

17 20 27 36 40 43 50 52 56 57 58 68
69 70 72 81 82 84 90 93 94 105 108 110
111 112 113 115 116 121 122 123 127 129 131 146
151 165 170 171 172 173 187 189 190 202 203 210
211 214 215 216 218 219 220 227 230 236 241 242
243 247 250 251 252 253 257 258 260 264 274 278
281 285 287 288 290 295 296 298 300 308 311 313
317 319 320 321 323 325 326 328 359 362 363 365
366 367 376 389 390 391 397 400 401 401 404 405
411 412 426 431 444 445 447 449 450 451 476 489
508 509 510 511 512 513 514 515 516 517 518 519
534 535 545 546 550 561 584 590 592 605 608

8. OTHER TEXAS LOCATIONS

6 12 16 17 20 23 25 36 40 43 56 57
58 64 65 66 67 68 69 70 71 72 81 82
90 91 93 94 95 95 105 107 108 110 111 112
113 115 116 121 122 123 127 129 131 137 145 146
151 165 170 171 172 173 185 187 189 190 210 214
215 216 218 219 220 227 230 231 236 241 242 243
250 251 252 257 260 264 277 278 281 285 287 288
290 295 296 301 308 311 313 316 319 320 321 323
325 326 328 362 363 366 376 390 391 397 401 404
405 411 412 413 417 426 431 440 444 445 447 448
449 454 462 465 466 476 478 494 507 508 509 516
517 518 519 529 531 532 533 534 535 536 537 545
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27 41 50 54 56 65 66 238 240 248 250 251
252 274 278 286 490 569

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12 14 22 27 36 41 50 51 56 58 59 65
66 69 70 71 73 81 81 86 87 89 90 94
96 102 108 109 110 112 115 116 117 122 126 127
129 132 137 144 145 146 151 152 172 173 174 200
202 205 211 215 218 219 230 231 238 239 250 251
252 253 254 257 270 276 278 284 285 293 308 311
313 318 320 323 348 349 350 362 366 370 382 383
389 391 395 401 405 410 411 412 426 432 439 444
445 449 450 451 454 464 482 494 496 507 509 510
511 512 513 515 516 517 518 519 562 582 590 592
598 606 607 608

2. PH

12 14 22 36 54 58 65 66 69 70 71 73
76 81 86 90 94 102 109 110 122 126 127 129
132 151 152 172 173 174 200 205 211 215 218 231
238 239 240 253 254 257 270 278 288 311 313 318
320 362 389 391 401 405 410 411 412 426 431 449
490 509 516 517 518 519 562 590 592 598

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3 12 14 36 50 51 58 65 66 69 70 71
73 76 81 86 90 94 102 108 109 110 114 116
122 126 127 128 129 132 151 152 172 173 174 200
205 211 214 215 218 230 231 238 239 240 243 253
254 257 270 278 288 293 295 298 311 313 317 318
319 320 321 362 389 391 401 405 410 411 412 416
426 431 444 445 490 496 509 511 512 513 516 517
518 519 562 590 592 598

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117 122 127 132 172 173 174 190 215 218 231 253
254 257 270 278 286 288 292 295 296 311 313 318
320 325 326 362 389 401 405 411 412 416 426 429
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325 326 362 389 401 403 404 404 405 411 412 426
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76 86 90 94 110 114 121 122 125 126 127 129
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270 288 295 296 298 308 311 313 318 320 325 326
331 360 362 389 401 404 405 406 411 412 426 431
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3 12 14 18 22 36 50 51 56 57 58 65
66 69 70 71 73 76 81 86 89 90 94 96
102 109 110 115 116 122 126 127 128 129 132 136
137 144 151 152 172 173 174 190 205 215 218 230
231 238 239 240 251 252 253 254 257 270 275 276
278 284 285 288 293 295 296 298 305 308 311 313
317 318 319 320 323 325 326 362 389 391 401 404
405 410 411 412 426 431 444 445 449 489 507 509
516 517 518 519 538 540 562 590 592 598 605

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12 14 36 50 54 69 70 71 76 90 94 110
116 121 125 126 127 151 152 172 173 174 201 205
215 218 230 231 238 243 251 253 254 257 270 276

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285   298   308   311   313   318   320   337   362   389   401   405
410   411   412   426   449   509   516   517   518   519   562   590
592
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9. SEDIMENTS

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 16    25    51   102   253   442   492   493
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10. DISSOLVED SOLIDS

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 12    14    36    50    51    56    57    58    59    66    69    70
 71    73    76    81    86    87    89    90    94    96   102   108
109   110   112   115   116   122   126   127   129   132   137   144
146   151   152   172   173   174   201   205   215   218   219   230
231   238   239   250   251   252   253   254   257   270   275   276
284   285   293   295   298   308   311   313   318   320   323   325
326   362   389   391   401   404   405   410   411   412   426   431
444   445   449   507   509   516   517   518   519   562   590   592
598   605
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11. TEMPERATURE

```
  1     2     6    12    14    23    27    36    41    50    54    59
 62    65    66    69    70    71    73    76    81    86    90    91
 94   102   109   110   112   114   115   116   117   122   123   126
127   128   129   132   137   144   151   152   155   171   172   173
174   201   202   203   205   210   211   215   218   231   233   238
239   240   251   252   253   254   255   257   270   274   276   278
285   286   287   293   296   303   308   311   312   313   318   320
321   348   349   350   362   389   391   401   405   411   412   419
426   431   444   445   449   450   454   481   490   491   497   499
501   507   509   510   511   512   513   515   516   517   518   519
538   551   562   582   590   592   598   606   607   608
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12. HUMIDITY

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 12    36    91   123   127   215   218   296   313   318
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12 14 36 50 54 57 65 66 69 70 71 73
76 81 90 94 102 110 113 116 121 122 126 127
151 152 172 173 174 201 205 215 218 231 238 239
243 251 253 254 257 270 276 285 311 313 320 337
358 362 389 391 401 405 410 411 412 426 431 449
509 511 516 517 518 519 562 590 592 598

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121 123 127 132 146 189 215 218 220 270 285 287
290 311 313 320 335 354 355 356 404 412 431 544
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375 544 563 564

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14 36 52 66 67 69 70 91 94 120 121 123
127 146 185 187 189 215 218 257 285 290 313 320
376 377 412 431 449 598

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89 90 91 94 99 108 121 122 126 127 128 137
144 146 151 152 172 173 174 189 190 201 202 203
205 214 215 218 219 230 231 238 239 250 251 252
253 254 255 275 278 284 285 287 288 293 295 298
308 311 313 318 320 323 325 326 362 366 389 391
401 404 405 410 411 412 426 431 444 445 449 501
507 508 509 516 517 518 519 545 546 562 590 592
598 605

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462 498 502 521 536 537 578

B. DRAINAGE SYSTEMS (WATER SHED)

13 14 36 57 66 67 69 70 71 83 90 94
99 108 122 123 127 132 146 151 174 185 187 189
190 198 205 215 218 219 230 231 238 257 270 285
313 349 356 375 376 377 385 389 401 404 411 412
416 426 448 462 498 537 578 592 598 605

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204 333 385 462 551

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325 326 366 404 405 412 431 449 590 592 609

A. GROUND WATER QUALITY

101 166 220 226 249 282 283 322 467 476 536 599

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226 249 283 467 483 484 594

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99 337 569 570

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169 367 375 400 521 569 570

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51 59 65 102 117 152 230 231 367 496 518 569
570

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```
  4   12   13   14   15   19   21   22   23   27   30   36
 41   50   51   54   56   57   58   65   66   69   70   71
 76   81   86   87   89   90   94   96  102  108  109  110
112  114  115  116  121  122  125  126  127  128  129  132
137  144  145  146  151  152  166  168  172  173  174  190
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323  325  326  346  362  366  389  391  401  401  404  405
410  411  412  426  431  442  444  445  449  465  472  493
507  508  509  516  517  518  519  536  562  569  570  572
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573 590 592 598 605

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12 14 36 51 58 69 70 90 94 109 114 123
127 128 132 137 172 173 174 201 205 215 218 226
230 231 238 249 253 254 257 270 278 288 293 295
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401 405 411 412 426 431 444 445 449 509 516 517
518 519 562 590 592 598

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11 21 136 154 167 168 232 264 319 339 365 372
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11 12 14 16 25 52 59 65 67 72 83 89
90 92 94 97 109 110 112 122 123 132 137 144
185 187 189 195 238 250 268 276 285 287 293 298
311 313 320 321 349 350 355 356 363 366 376 377
389 411 412 440 490 509 516 518 534 550 561 572
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30 36 51 69 70 90 94 127 215 253 257 270
311 313 320 321 404 411 412 426 464 489 496 590
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1 2 26 56 65 67 73 86 91 92 102 106
116 120 132 146 151 152 160 185 187 198 219 248
250 276 284 285 286 288 290 292 302 318 321 348
376 377 382 383 410 413 429 431 432 439 443 447
482 490 494 496 515 516 596

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18 30 36 65 69 70 71 73 90 91 94 120
123 125 127 146 189 215 270 285 293 311 313 321
325 326 404 412 413 431 449 590 598

B. SHRUBS

18 30 36 65 69 70 71 73 90 91 94 120
123 125 127 146 189 215 270 285 293 311 313 319
321 325 326 404 412 413 431 449 590 598

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1 2 14 18 30 36 56 59 65 69 70 71
73 86 89 90 91 94 102 106 108 109 110 116
120 121 123 125 126 127 132 146 174 189 190 205
214 215 219 250 257 270 276 284 285 293 308 311
313 318 319 320 321 323 325 326 366 389 404 410
411 412 413 431 449 546 550 590 598

D. FORBS

18 30 36 56 59 65 69 70 71 73 86 89
90 91 94 102 108 109 110 116 120 121 123 125
126 127 132 146 174 189 190 205 214 215 219 250
257 270 284 285 293 311 313 318 319 320 321 323
325 326 366 389 404 410 411 412 413 431 449 546
590 598

E. CROPS

14 36 90 94 120 189 190 214 215 270 311 313
319 321 325 326 366 404 412 449 590 598

F. MICROFLORA AND FUNGI

14 22 30 36 56 65 69 70 71 73 76 90
94 102 108 109 110 114 116 121 125 126 127 132
151 152 172 174 189 190 205 215 219 230 250 251
253 254 257 270 275 276 288 293 298 311 313 318
320 321 323 362 366 389 404 411 412 413 426 431
449 501 519 562 590 598

G. AQUATIC PLANTS

1 2 14 22 30 36 56 59 65 69 70 71
73 76 86 89 90 94 102 106 108 109 110 116
120 121 125 126 127 132 146 151 152 172 174 189
190 205 214 215 219 230 250 257 270 275 276 284
285 288 293 298 308 311 313 318 320 321 323 362
366 389 404 410 411 412 413 426 429 431 442 519
526 546 590 598

H. DOMINANT SPECIES (PLANTS)

1 2 22 36 56 65 69 70 71 73 86 90
91 94 102 106 108 109 110 116 120 123 125 127
132 146 152 174 189 190 205 214 215 219 250 257
270 284 285 288 293 311 313 318 321 323 362 366
389 404 410 411 412 413 426 429 431 449 546 590
598

I. PHYTOPLANKTON

22 98 106 155 205 254 431 449 490 491

3. INVERTEBRATES

A. BENTHIC INVERTEBRATES

4 14 19 27 36 54 59 61 65 66 69 70
71 76 81 90 94 96 106 108 109 110 115 116
121 125 126 127 128 137 172 174 190 205 214 215
219 230 231 251 253 254 257 270 284 287 293 302
311 313 321 323 325 326 337 350 358 359 360 362
366 389 401 403 404 405 406 411 412 413 418 426
431 449 464 471 492 508 513 516 518 519 519 562
590 598

B. CRUSTACEA

6 12 14 19 23 27 36 41 57 59 61 65
66 69 70 71 81 90 94 95 96 108 109 110
112 116 125 126 127 128 137 144 172 174 190 200
201 205 214 215 219 230 231 238 239 240 250 252
253 254 257 270 274 278 284 287 293 308 311 313
318 321 323 325 326 348 349 350 359 366 389 391
401 401 404 405 406 411 412 413 418 426 431 449
450 451 464 468 490 492 493 507 508 510 511 514
516 518 519 545 546 562 590 592 598 605 608

C. INSECTS

36 57 66 69 70 71 81 90 94 96 109 116
125 127 137 189 190 205 215 219 257 270 293 311
313 325 326 404 405 412 413 426 431 449 519 590
592 598

D. OTHER INVERTEBRATES

19 27 36 54 58 65 66 69 70 71 76 81
90 94 96 109 110 115 116 125 127 128 136 137

174 190 205 211 215 219 231 251 254 257 270 287
293 311 313 321 323 325 326 348 350 359 389 401
404 405 411 412 413 418 426 431 449 464 493 508
516 518 519 540 562 582 590 592 598

E. ZOOPLANKTON

23 58 98 155 302 348 350 431 449 515 519

4. VERTEBRATES

A. FRESH WATER FISH

57 90 94 293 295 298 311 313 321 323 325 326
366 389 404 405 412 413 426 431 449 501 509 519
590 598

B. MARINE FISH

7 27 42 50 61 65 66 90 94 242 250 255
274 287 293 295 298 311 313 321 323 325 326 366
389 390 404 405 411 412 413 426 431 449 490 501
509 516 517 518 519 562 569 590 598

C. COMMERCIAL FISH

3 19 36 66 71 89 96 107 110 116 125 126
127 128 129 136 137 144 147 174 189 190 202 203
204 205 214 215 219 230 238 241 242 250 253 254
255 257 270 298 302 303 312 321 348 350 359 389
390 405 431 442 449 450 451 453 454 464 466 469
492 493 499 501 509 511 512 517 519 538 540 606

D. OTHER FISH

1 2 3 7 12 14 19 27 36 42 50 59
61 65 66 69 70 71 89 96 107 108 110 112

116 125 126 127 128 129 136 137 144 147 155 172
174 190 202 203 205 214 215 219 238 239 250 253
254 255 257 270 274 295 298 302 312 321 348 350
359 370 389 390 405 406 413 442 449 450 451 464
469 481 490 492 493 497 499 509 511 512 517 519
538 607

E. AMPHIBIANS AND REPTILES

19 36 69 70 71 90 94 125 126 127 174 189
190 215 219 257 270 311 313 404 405 412 413 431
499 590 598

F. BIRDS

14 36 59 65 69 70 71 90 94 108 110 116
123 125 126 127 132 137 174 189 215 219 250 257
270 311 313 325 326 404 411 412 413 426 431 449
562 590 598

G. MAMMALS

36 69 70 71 90 94 110 123 125 126 127 174
189 215 219 250 257 270 296 311 313 404 411 412
413 426 431 478 590 598

5. ENDANGERED SPECIES

36 90 94 127 174 189 215 219 257 270 311 313
404 405 411 412 431 592

6. SPECIES LISTS

27 71 73 120 248 274 287 390 450 507

E. ECOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS

1. PRODUCERS

1 2 14 18 19 22 30 36 54 56 59 65
69 70 71 73 76 86 89 90 91 94 102 106
108 109 110 114 116 120 121 123 125 126 127 132
146 151 152 174 189 190 205 214 215 218 219 230
250 253 254 257 270 275 276 284 285 286 288 292
293 308 311 313 318 319 320 321 323 325 326 362
366 389 404 410 411 412 413 426 429 431 449 490
519 550 562 584 590 598

2. CONSUMERS

1 2 12 14 18 19 23 27 36 41 42 50
54 57 58 59 61 65 66 69 70 71 76 81
89 90 94 95 96 108 109 110 112 115 116 121
123 125 126 127 128 129 137 144 147 174 189 190
200 201 202 203 205 214 215 218 219 230 231 238
239 250 251 252 253 254 255 257 270 275 276 278
284 286 287 288 293 295 296 298 308 311 313 318
321 323 325 326 366 389 390 391 401 404 405 411
412 413 426 431 449 490 501 507 508 509 516 517
518 519 545 546 562 584 590 592 598 605

3. DECOMPOSERS

36 51 69 70 71 76 86 90 94 108 127 214
215 218 253 254 257 270 311 313 320 321 404 411
412 413 426 584 590 598

4. POPULATION DYNAMICS

4 4 12 22 27 30 36 41 50 54 61 65
66 69 70 71 73 76 81 89 91 94 95 102
107 108 109 112 114 115 121 123 127 147 151 152
170 174 189 200 201 202 203 205 215 219 231 238
241 242 250 251 252 253 254 255 257 270 275 278
285 287 288 293 298 303 308 308 311 313 318 320
321 323 348 350 359 362 366 383 389 390 391 401
410 411 412 413 426 431 449 450 451 453 491 494
501 507 509 510 511 513 514 515 516 517 518 519

530 545 546 550 562 582 590 592 598 605 608

5. SYSTEMS ECOLOGY

1 2 12 14 15 18 22 27 30 36 41 50
51 54 56 57 59 61 65 66 69 70 71 73
76 81 86 89 90 91 94 95 102 105 107 108
109 110 111 112 113 114 115 116 117 120 121 122
123 125 126 127 128 129 132 137 144 146 151 152
155 174 189 190 201 202 203 205 210 214 215 218
219 230 231 238 239 250 251 252 253 254 255 257
265 268 270 275 276 278 284 285 287 288 288 293
295 296 298 299 308 311 313 318 319 320 321 323
325 326 362 366 389 390 391 401 404 405 410 411
412 413 426 430 431 449 485 501 507 508 509 516
517 518 519 530 545 546 550 562 584 590 592 596
598 605

6. HABITAT

12 14 15 18 22 23 27 30 36 41 42 50
51 54 56 57 58 61 65 66 69 70 71 73
76 81 86 87 89 90 91 94 102 106 108 109
112 114 115 116 120 121 122 123 125 126 127 128
129 132 137 144 146 151 152 173 174 189 190 200
201 202 203 205 214 215 218 219 230 231 238 239
250 251 252 253 254 255 257 270 275 278 284 285
287 288 293 295 296 298 303 308 311 313 318 319
320 321 323 325 326 362 366 389 390 391 401 404
405 410 411 412 413 426 431 444 445 449 501 507
508 509 516 517 518 519 545 546 550 562 584 590
592 598 605

7. FOOD CHAINS

1 2 14 18 36 42 54 61 69 70 71 73
76 94 121 125 126 127 189 190 205 215 218 252
270 275 298 308 311 313 318 325 326 389 404 411
412 413 426 546 562 590 592 598

8. BEHAVIOR

6 12 42 50 54 58 59 61 69 70 76 89
94 125 126 127 128 129 144 189 200 201 202 215
218 219 230 231 270 295 311 313 318 321 323 389
405 411 412 426 449 508 509 516 517 518 519 590
592 598 605

9. GROWTH (INCLUDING MOLTING)

3 6 12 22 30 36 42 56 58 61 73 76
94 102 106 115 127 129 132 144 151 152 201 211
215 218 219 252 270 285 288 293 295 298 311 312
313 321 359 362 389 391 410 411 412 413 426 429
432 439 508 512 514 517 550 590 592 598 607 608

A. LARVAL STAGES AND REPRODUCTION

3 6 42 54 61 128 129 147 211 240 337 359
370 391 454 469 471 481 482 514 582 608

10. METABOLISM (INCLUDING RESPIRATION)

1 2 18 19 22 23 36 51 56 57 58 69
70 76 94 96 106 107 108 109 110 114 115 116
121 122 127 128 129 132 144 151 152 174 201 215
218 219 252 255 270 275 276 278 285 288 293 295
296 298 308 311 313 318 319 320 321 323 325 326
358 362 404 405 410 411 412 413 426 439 486 499
501 507 508 509 550 590 592 598 605 606 607

11. OSMOREGULATION

36 56 69 70 81 94 127 137 144 146 174 215
218 219 230 231 250 257 270 278 293 311 313 323
370 405 412 426 480 501 509 516 518 590 592 598

12. SEASONAL VARIATION

2 6 27 36 41 50 54 59 61 65 69 70
71 73 86 89 90 94 95 102 108 112 114 120
122 123 126 127 128 132 137 144 146 147 151 152

173 174 189 200 201 202 203 205 215 218 219 230
231 238 241 242 254 270 287 293 298 308 311 312
313 318 348 360 362 366 389 390 391 411 412 413
429 431 486 490 494 507 509 510 511 512 515 516
517 518 519 545 546 562 584 590 592 598 606 607
608

13. REVIEWS, BIBLIOGRAPHIES, ETC.

7 15 26 36 69 70 76 90 93 94 110 122
127 128 144 146 170 174 189 190 198 214 215 218
219 233 243 270 285 286 302 308 313 319 320 321
323 325 326 331 378 404 404 405 411 412 414 416
425 426 431 433 439 453 472 478 494 524 584 590
592 596

14. TOXICITY

3 6 14 15 18 19 22 23 30 36 51 54
56 57 64 69 70 71 73 76 81 89 90 94
96 112 115 122 123 127 128 129 144 173 174 190
202 203 211 214 215 218 219 230 231 239 240 251
252 253 254 255 257 270 278 285 288 293 295 296
298 303 308 311 312 313 316 318 319 320 321 323
325 326 360 362 382 389 401 404 405 410 411 412
418 426 431 464 469 471 480 486 489 496 501 508
509 510 512 516 518 538 540 582 590 592 598 605

A. PESTICIDES AND HERBACIDES

14 331 497

15. OLFACTION

36 215 218 270 313 319

16. SPECIES DIVERSITY

12 14 27 30 36 50 65 66 69 70 71 73
81 91 94 109 110 116 127 146 174 189 200 203
205 215 218 219 230 231 253 254 257 270 313 318
389 390 411 412 431 516 518 519 546 562 584 590
592 598

17. GENETIC VARIATION WITHIN SPECIES

36 59 174 215 218 270 313 508

18. ECOSYSTEM STABILITY

14 36 50 56 59 69 70 71 73 81 89 90
94 109 110 115 116 123 125 126 127 128 129 174
203 205 214 215 218 219 230 231 238 239 250 253
254 257 270 285 287 288 293 295 298 311 313 318
319 320 321 323 366 389 401 410 411 412 426 444
445 508 509 516 518 519 546 562 584 590 592 598
605

19. INDICATOR ORGANISMS

30 36 50 56 69 70 76 91 94 109 120 121
127 128 129 144 146 174 189 215 218 231 250 253
254 257 270 278 287 288 295 298 313 318 319 320
323 325 326 366 389 404 405 411 412 426 508 509
516 517 518 519 546 590 592 598 605

20. COMMUNITIES

1 2 14 30 36 42 50 51 56 65 66 69
70 71 73 76 81 86 91 94 102 108 109 110
114 115 116 120 123 125 126 127 128 129 132 146
151 152 174 189 201 203 205 214 215 218 230 231

238 250 253 254 257 270 276 284 285 287 308 313
318 320 323 389 410 411 412 509 516 518 546 584
590 592 598

21. EXTINCTION

36 41 50 65 69 70 71 91 94 102 106 108
114 115 127 146 151 152 173 174 200 201 202 203
205 215 218 219 230 231 238 270 313 318 323 412
516 518 535

22. ECOTYPES

36 91 121 127 174 215 257 270 313 318 411 412

23. BARRIERS AND CORRIDORS

36 94 127 174 215 230 231 250 270 285 298 313
318 323 412 509 516 518 546 598

24. DISTRIBUTION OF ORGANISMS

87 27 98 120 160 274 454 494 507

F. BIOLOGICAL COMMUNITIES

67 185 187 198 290 376 377

1. RIVER BAYOU

13 14 19 22 23 30 36 41 50 56 57 59
66 71 76 81 87 89 90 94 96 108 110 112
120 121 122 125 126 127 128 129 136 137 144 146
147 152 155 156 172 173 174 189 190 201 202 203

205 210 214 215 218 219 230 231 239 250 252 255
257 270 276 278 284 285 288 293 295 296 298 303
308 311 313 319 320 321 323 325 326 362 366 389
391 401 403 404 405 411 412 413 416 426 431 444
445 449 489 501 507 509 510 512 513 515 516 518
519 545 546 584 590 592 598 605

2. LAKE AND POND

19 22 23 30 36 56 57 59 71 76 81 89
90 94 95 96 98 108 110 114 120 121 122 125
126 127 128 129 144 146 147 172 173 174 189 190
201 205 211 214 215 218 219 230 231 255 257 270
284 285 288 293 295 308 311 313 319 320 321 323
325 326 362 366 389 391 401 404 405 411 412 413
418 426 431 449 468 486 508 509 511 516 518 519
584 590 592 598 605

3. SWAMP

57 90 94 121 123 278 284 285 288 293 295 296
311 313 319 320 321 325 326 362 366 391 404 412
413 431 449 584 590 592 598 605

4. BAY AND ESTUARIES

1 2 4 6 7 13 14 15 16 19 23 26
27 30 36 41 42 50 51 54 56 57 59 61
64 65 66 69 70 71 76 81 86 87 89 90
91 94 95 96 102 105 106 107 108 109 110 111
112 113 114 115 116 120 121 122 125 126 127 128
129 132 137 137 144 146 147 151 152 160 170 171
172 173 174 190 200 201 202 203 211 214 215 218
219 230 231 231 238 239 240 241 242 250 251 252
253 254 257 270 274 275 276 278 284 285 287 288
292 293 295 298 308 311 313 319 320 321 323 325
326 331 347 349 350 358 359 360 362 366 378 383
389 391 395 401 401 404 405 410 411 412 413 426
429 430 431 443 444 445 449 450 451 454 464 471
472 478 481 490 492 493 494 496 507 509 510 513
516 517 518 519 545 546 550 582 584 590 592 598
604 605 606 607 608

5. MARINE

4 5 6 12 19 22 27 30 36 41 42 56
57 58 61 65 69 70 81 89 90 94 95 96
102 106 109 112 116 121 128 137 144 146 147 151
152 190 200 201 202 203 215 218 219 231 238 239
250 252 257 270 276 278 284 285 287 288 293 295
298 308 311 313 318 321 323 325 326 362 366 389
390 391 401 404 405 410 411 412 413 426 431 444
445 449 507 508 509 516 517 518 519 545 562 584
598

A. OPEN GULF

144 36 152 171 200 278 347 390 391 405 426 466
472 478 569 570

6. URBAN

18 30 57 90 94 215 218 219 278 288 296 308
311 319 320 321 325 326 401 404 405 411 412 426
431 444 445 508 509 516 517 518 519 545 546 584
590 592 598 605

7. GRASSFLATS

30

8. HYPERSALINE

56 65 81 109 116 359 370 395 490

9. SANDFLATS

36 59 65 66 91 94 120 146 174 189 215 218
219 257 270 287 296 313 325 326 404 411 412 413
431 449 508 584 590 598

10. BEACH AND SURF

19 22 36 56 59 65 90 94 120 121 127 144
146 189 190 215 218 219 239 257 287 288 293 295
296 311 313 320 321 323 325 326 362 391 404 411
412 413 431 449 508 584

11. DUNE AND BARRIER FLAT

36 90 91 93 94 120 146 174 189 215 218 219
257 296 313 319 326 404 411 412 413 449 482 584

12. SALT MARSH

19 22 30 36 42 51 56 57 59 65 66 69
70 71 81 86 90 94 95 96 108 109 110 111
112 114 116 117 120 121 122 123 125 126 127 128
129 132 137 144 146 147 152 164 172 173 174 189
190 201 202 203 214 215 218 219 238 239 250 252
257 270 278 284 285 286 287 288 293 295 296 308
311 313 318 319 320 321 323 325 326 362 366 375
389 391 401 404 405 411 412 413 429 431 432 449
468 493 494 496 507 508 509 516 517 518 519 530
545 546 550 584 590 596 598 604

13. FRESH WATER MARSH

19 23 36 56 57 59 71 73 76 89 90 94
96 108 110 111 112 120 121 122 125 126 127 128
129 132 144 147 172 173 174 189 190 201 205 215
218 219 230 255 257 270 278 284 285 286 288 293
295 296 308 311 313 319 320 321 323 325 326 362
366 389 391 401 404 405 411 412 413 431 444 445
449 517 519 584 590 592 596 598 605

14. MUDFLATS

15. PRAIRIES AND GRASSLANDS

36 65 71 90 91 94 120 123 127 146 174 189
215 218 219 296 313 319 325 326 401 404 412 413
449 584 590 598

16. RIVERINE

19 22 36 41 66 90 94 120 125 126 127 146
174 189 190 205 215 218 219 230 285 296 313 319
325 326 401 404 412 413 431 449 584 590 598

17. MIXED PINE AND HARDWOOD

36 90 94 120 123 127 189 215 218 219 296 313
319 325 326 404 412 449 584 590 598

18. SAVANNAH

36 90 94 120 123 127 189 215 218 219 296 313
319 325 326 404 412 413 449 584 590 598

19. OAK MOTTES AND GROVES

36 90 94 123 146 189 215 218 219 296 313 319
325 326 404 412 449 584 590 598

20. FLOOD PLAIN FOREST

36 71 90 94 108 120 123 127 146 189 190 215
218 219 230 285 296 313 319 325 326 401 404 412
413 431 449 584 590 598

21. INLAND EOLIAN COMMUNITIES

36 90 94 146 189 215 218 219 296 325 326 404
584

22. BRUSHLAND

36 65 71 90 91 94 120 123 127 146 174 189
215 218 219 296 313 319 325 326 404 412 413 431
449 584 590 598

III. NATURAL, CULTURAL AND ENERGY RESOURCES

A. LOCATION

1. U. S.

5 11 17 20 26 98 107 111 119 124 170 171
176 184 191 210 216 229 233 248 291 292 302 303
305 312 315 320 321 327 353 364 368 371 392 395
396 403 407 420 455 455 457 477 495 504 538 539
542 548 549 573 575 576 576 576 580 586 593 594
601 609 613 614

2. GULF COAST -- TEXAS, LOUISIANA

5 29 32 55 74 80 127 140 142 143 156 163
181 188 192 193 196 259 263 264 273 279 280 281
317 333 369 393 399 422 423 424 436 437 461 483
541 549 577 583 597

3. NOT TEXAS OR LOUISIANA

5 21 53 69 70 73 86 98 102 116 121 127
146 157 173 210 214 215 219 245 255 257 292 324
375 399 403 438 481 491 497 524 566 604

4. TEXAS

44 47 62 65 67 69 70 71 78 81 91 105
107 108 115 116 121 127 145 146 151 155 162 172
173 176 184 186 208 209 214 215 216 218 219 230
231 233 243 246 257 285 289 290 291 292 299 302
305 312 320 321 330 364 384 391 392 395 403 406
407 408 455 457 462 466 477 536 537 538 539 540
542 549 576 579 593 594 609 613

A. WILLACY-CAMERON FAIRWAY

71 127 184 215 216 218 219 233 244 299 312 319
320 364 407 408 455 457 477 507 539 549 576 593
594 609 613

B. KENEDY FAIRWAY (ARMSTRONG PROSPECT)

184 215 216 218 219 233 291 299 302 303 306 312
315 320 321 327 351 352 353 364 368 371 387 388
395 407 408 455 457 477 507 539 549 576 593 594
609 613

C. NUECES-CORPUS CHRISTI FAIRWAYS

15 25 36 62 69 70 81 108 115 116 119 121
127 146 151 152 155 176 184 214 215 216 218 219
233 243 254 257 291 292 294 299 312 315 327 364
368 392 403 406 407 408 410 455 457 477 492 538
539 540 542 543 549 576 593 594 609 613

D. MATAGORDA FAIRWAYS

36 62 69 70 81 108 115 116 119 121 127 146
151 155 176 184 214 215 216 218 219 233 243 257
292 299 312 319 320 327 364 368 392 395 403 406

407 408 455 457 477 538 539 540 542 549 576 593
594 609 613

E. BRAZORIA FAIRWAY (CHOCOLATE BAYOU PROSPECT)

36 50 62 69 70 81 108 115 116 119 121 127
146 151 155 172 173 176 184 194 202 203 211 214
215 216 218 219 233 243 253 257 285 291 292 299
302 305 312 319 320 321 364 392 395 401 403 406
407 408 455 457 477 509 511 512 513 514 515 517
518 519 538 539 540 542 549 576 593 594 609 613

F. SOUTH TEXAS

(BROOKS, CAMERON, HIDALGO, JIM HOGG, KENEDY,
KLEBERG, NUECES, STARR, WILLACY AND WILLS COUNTIES)

45 83 244 421 463 526 527 602

G. MIDDLE TEXAS GULF COAST

(ARANSAS, CALHOUN, JACKSON, MATAGORDA, REFUGIO,
SAN PATRICIO, VICTORIA AND WHARTON COUNTIES)

47 222 376 377 484

H. UPPER TEXAS GULF COAST

(BRAZORIA, CHAMBERS, FORT BEND, GALVESTON, HARRIS,
JEFFERSON, LIBERTY AND ORANGE COUNTIES)

48 179 185 277 376 400 417

I. TEXAS OFFSHORE

179

5. LOUISIANA

31 47 62 69 70 97 108 119 121 125 127 133
134 135 146 147 155 160 176 180 184 198 201 205
214 215 216 219 228 233 235 243 264 282 283 284
292 299 302 303 305 306 309 312 315 316 319 320
321 327 332 339 340 341 342 343 344 345 351 352
353 358 364 368 371 373 387 388 395 403 406 407
408 431 455 457 466 467 468 471 477 496 498 502
503 520 521 522 538 539 540 542 549 576 582 593
594 599 609 613

A. LAKE CHARLES AREA
(CALCASIEU, JEFF DAVIS, AND CAMERON PARISHES)

47

B. LAFAYETTE AREA
(ACADIA, VERMILION, IBERIA, ST.MARY, ST.MARTIN AND LAFAYETTE PARISHES)

92 99 164 180 304 335 336 355 544 563

C. HOUMA AREA
(IBERVILLE, ASSUMPTION, TERREBONNE, LAFOURCHE AND ST.CHARLES PARISHES)

334 354 356 564

E. LOUISIANA OFFSHORE

193 569 570 571

6. OTHER
(ICELAND, EL SALVADORE, USSR, MEXICO, WESTERN U.S.)

28 62 156 158 184 216 217 233 291 302 305 312

320 321 332 351 352 361 379 380 387 392 395 407
408 455 457 477 538 540 543 547 549 585 593 594
609 613 614

B. NATURAL RESOURCES

1. BIOLOGICAL RESOURCES (SEE II)

2. MINERAL RESOURCES

67 177 185 187 198 376 377 379 505

3. WATER

62 155 175 176 216 233 285 291 292 294 299 302
303 310 312 321 371 395 408 414 420 495 538 542
549 576 585 614

A. SURFACE WATER SUPPLIES - REQUIREMENTS

62 98 155 171 225 282 299 315 355 462 551 578

B. GROUND WATER SUPPLIES - REQUIREMENTS

133 222 277 282 283 315 461 467 483 484 551 599

C. CULTURAL RESOURCES

1. LAND USE

10 11 21 40 62 67 97 104 107 111 119 124
127 155 156 157 160 165 170 171 175 176 182 184
185 187 191 198 199 210 211 214 216 223 233 240
243 258 262 265 268 274 290 292 294 299 306 310
312 315 320 321 351 352 353 368 371 376 377 387
392 395 406 407 408 420 455 540 542 548 549 576
585 594 609 614

A. REFUGES, WILDERNESS AND OPEN SPACES

36 64 90 93 94 123 127 174 214 215 218 219
296 313 319 325 326 328 404 449 488 584

B. WETLANDS

64 82 93 131 241 242 328 488 534

C. FORESTRY

82

D. GRAZING

82 328

E. AGRICULTURE

10 328

F. MARICULTURE

468 511 514

G. FISHERY

47 201 205 308 378 391 431 466 507 511 569 570

H. RESIDENTIAL

82 93 328 534

I. COMMERCIAL

82 241 242 328

J. INDUSTRIAL

82 177 241 242 328 488 505 534

K. MINING AND QUARRYING

177

2. RECREATION

A. HUNTING

93 328

B. FISHING AND WATER SPORTS

64 82 93 131 241 242 328

C. LAND ORIENTED RECREATION

93 328

D. RESORTS

93 328 534

3. AESTHETICS AND HUMAN INTEREST

A. SCENIC VIEWS AND VISTAS, WILDERNESS AND OPEN SPACE QUALITIES

63 64 93 131 241 242 328 488

B. UNIQUE PHYSICAL FEATURES

93 93 505 600

C. MONUMENTS, PARKS AND RESERVES

93 328

D. RARE AND UNIQUE SPECIES OR ECOSYSTEMS

93 328

4. CULTURAL STATUS

A. CULTURAL PATTERNS (LIFE STYLE)

63 64 82 93 241 242 281 488 534

B. HEALTH AND SAFETY

64 21 131 165 534

C. POPULATION DENSITY

21

5. MAN-MADE FACILITIES AND ACTIVITIES

67 185 187 376 377

A. STRUCTURES

82 93 488 534

B. TRANSPORTATION NETWORK (MOVEMENT, ACCESS)

82 93 534

C. UTILITY NETWORKS

93

D. BARRIERS

82 93 534

E. CORRIDORS

82 93 534

D. ENERGY RESOURCES

1. GEOTHERMAL RESOURCES

A. GEOPRESSURED-GEOTHERMAL RESOURCES

33 35 45 53 79 142 153 212 235 281 394 397
399 421 458 460 551 575 576 595

B. OTHER GEOTHERMAL RESOURCES

5 10 11 21 24 28 34 38 40 53 60 88
104 113 118 124 129 138 149 157 160 164 165 182
191 197 212 217 223 224 233 240 245 256 258 260
267 271 272 274 397 460 473 500 551 575 576 600
601

1. DRY STEAM FIELDS

10

2. MAGMATIC DEPOSITS

397

3. GEYSERS AND HOT SPRINGS

397 237 600

4. LIQUID-DOMINATED HYDROTHERMAL

141 177 567

5. VAPOR-DOMINATED HYDROTHERMAL

141 177 567

6. HOT DRY ROCKS

177

C. FORMATION OF GEOTHERMAL RESOURCES

142 143 194 279 280 281 397 595

D. DISTRIBUTION OF GEOTHERMAL RESOURCES

44 46 142 422

E. LOCATION OF GEOTHERMAL RESOURCES

47 142 153 164 235 527

F. DEVELOPMENT OF GEOTHERMAL RESOURCES

29 141 207 212 364 398 422 541 565 576 577 579
583 588 601

G. RESOURCE ASSESSMENT

55 140 142 143 163 164 197 207 212 235 263 297
364 396 399 422 526 541 565 577 588 597 601 602

H. ECONOMIC ANALYSES

60 79 142 157 158 261 277 333 364 369 394 396
399 435 436 437 452 458 553 554 588 602

I. NET ENERGETICS

79 588

J. OTHER ENERGY RESOURCES

1. COAL

62 155 184 216 302 303 310 312 319 320 321 395
406 457 477 538 542

2. NUCLEAR

62 127 155 156 175 176 184 210 216 229 233 243
262 274 302 303 310 312 320 321 395 403 457 477
538 542

3. OIL AND GAS

40 62 107 113 119 127 155 160 178 184 199 216
240 243 274 285 299 302 303 305 310 312 319 320
321 395 403 406 408 457 477 538 539 542 549 603
609

4. OIL SHALE

62 155 184 199 216 302 303 312 319 320 321 406
457 477 538 539 542

5. SOLAR

62 155 184 199 216 312 320 321 477

6. TIDAL

113 127 130 160 243 285 320

K. OTHER USES OF LOW-GRADE GEOTHERMAL ENERGY

88 104 118 130 142 149 156 157 191 233 262 312
351 352 353 387 396 455 456 459 548 593 595

1. INDUSTRIAL UTILIZATION

40 78 80 104 153 159 162 181 191 204 233 258
259 263 306 393 408 409 455 459 595

2. BENEFICIATION

80 191 306

L. ENERGY BUDGET

40 118 130 157 165 191 197 455 603

M. COGENERATION

62 155 184 216 233 256 291 302 303 306 312 320
321 351 352 395 477 538 542 549 593

E. GEOLOGICAL AND ENGINEERING RESEARCH AND TECHNOLOGY

1. GEOLOGY

A. GENERAL GEOLOGY

45 67 185 186 187 188 196 198 290 376 377 467

B. TERTIARY SEDIMENTS

44 135 281 422 423 424 526

C. WILCOX FORMATION

135

D. FRIO FORMATION

45 46 47 48 142 194 263 273 289 423 424 526

E. SMACKOVER FORMATION
(JURASSIC OVERPRESSURED SEDIMENTS)

423 424

F. LITHOLOGY

31 32 48 194 281

G. CLAYS (SEE IIC)

H. FORMATION PRESSURE

280 281 577

I. ABNORMAL PRESSURE

31 32 135 150 192 193 194 228 266 279 280 281
304 309 330 423 424 441 463 479 522 527 528 587

J. FAULTING (SEE IIC)

K. FORMATION WATER (CHEMISTRY)

37 273 280 479

1. GEOPRESSURED FORMATION WATER (CHEMISTRY)

55 134 141 194 279 289 479 487 522 577 587

2. METHANE CONTENT

47 55 164 235 289 487 577 587

3. SHALE WATER INFLUX

134 479 587

2. GEOLOGICAL ENGINEERING RESEARCH

A. GEOPRESSURE RESERVOIR

60 281 421 422 577

B. RESERVOIR MECHANICS - AQUIFER BEHAVIOR

31 55 142 164 297 421 422 436 463 527 539 541 577

C. SUBSURFACE GEOLOGICAL TECHNIQUES

142 150 309 436 463 522 526 527

D. COMPATIBILITY OF WATERS (INTRAFORMATIONAL PRECIPITATION)

157 247 591

E. TEMPERATURE

164 291 302 379 436 541 547 577 580

F. PERMEABILITY - POROSITY

31 44 142 164 247 297 397 423 424 441 463 479
483 526 527 541 577

G. PRESSURE (ABNORMAL PRESSURE DETECTION TECHNIQUES)

150 164 192 193 309 436 438 522 541 577

H. GEOTHERMAL GRADIENT (SEE ALSO IIC)

48 280 281 330 547 595

3. ENERGY SYSTEMS

A. ELECTRICITY GENERATING POWER PLANT

33 35 49 79 225 232 373 460 473 475 552 554
555 576 585 588

B. BINARY CYCLE CONVERSION SYSTEM

33 49 60 256 261 263 306 473 475 588

C. TOTAL FLOW CONVERSION SYSTEM

33 35 60 261 263 338 588

D. FLASHED STEAM CONVERSION SYSTEM

49 60 79 261 263 306 555 588

E. SECONDARY WORKING FLUID CYCLE

79 552 555 602

F. GEOHYDRAULIC ENERGY

235 263 552 577

G. METHANE (PRODUCTION, USE, FUEL PLANT)

263 369 388 399 552 554 577 602

H. SITE PLANNING

368 104 552 576 614

I. COOLING TOWERS - COOLING SYSTEMS

49 62 136 154 155 156 165 170 204 210 211 216
225 229 233 248 274 299 303 312 315 321 333 385
461 549 614

J. MINERAL EXTRACTION

100 182 207 305 332 388 395 504 595

4. WELL TECHNOLOGY, DISPOSAL SYSTEMS

182

A. DISPOSAL OF HOT WATER

37 141 157 158 165 176 299 302 303 312 321 473
500 552 583

B. DISPOSAL OF BRINE

8 9 37 75 100 101 139 141 158 165 244 299
338 340 341 342 343 344 452 473 476 484 503 520
552 553 583 591

C. DISCHARGE INTO MARINE WATERS (OFFSHORE)

37 107 171 176 240 299 302 303 312 321 503 540
542 569 570 571

D. DISCHARGE INTO RIVERS AND OTHER NATURAL SURFACE WATERS

37 145 155 191 216 292 312 321 503 520 538

E. REINJECTION (SUBSURFACE DISPOSAL)

8 9 37 39 75 103 139 157 158 161 166 216
221 246 247 261 322 338 345 381 384 394 415 428
438 470 473 475 483 500 503 525 536 553 591

F. EVAPORATION PONDS AND MAN-MADE SURFACE DISPOSAL SYSTEMS

9 37 428 462 549 553 554

G. SURFACE STORAGE (PONDS AND TANKS)

216 217 462 525

H. PIPELINES

375 434 435 614

I. WELL TECHNOLOGY AND DESIGN

8 39 77 103 139 143 158 217 247 345 384 436
437 446 506 522 528 574 576 577 595

1. WELL BORE HEAT TRANSMISSION

388 158 446 577

2. DRILLING TECHNOLOGY

77 135 299 374 396 402 436 437 522 556 557 558
559 560 576 612

J. SCALING AND CORROSION

8 37 75 77 101 157 158 183 184 217 223 232
291 327 384 388 402 543 556

K. WELL SPACING

77 157 421 422

L. DRILLING AND WELL STATISTICS

340 341 342 343 344 345 384

M. DISTRIBUTION OF EXISTING DISPOSAL WELLS

340 341 342 343 344

N. PRECAUTIONARY MEASURES

8 39 77 166 247 345 381 434 435 591 612

IV. GEOPRESSURED-GEOTHERMAL ENERGY EXPLOITATION ACTIVITIES THAT MAY CAUSE ENVIRONMENTAL IMPACT

A. MODIFICATION OF REGIME

1. MODIFICATION OF HABITAT

A. SUBMERGENCE FOLLOWING SUBSIDENCE AND/OR FLOODING

21 36 65 69 70 71 81 90 91 94 102 108
111 116 121 123 125 127 146 147 152 165 173 174
175 199 201 205 214 215 217 218 219 230 231 238
243 253 254 257 270 284 285 291 293 299 302 303
305 308 311 312 313 315 318 319 320 321 323 327
362 366 368 389 390 391 401 405 411 412 413 420
431 444 445 449 507 516 517 518 519 545 546 550
584 590 592 598

2. ALTERATION OF GROUND COVER DUE TO SUBSIDENCE

21 165 199 299 302 303 305 312 315 319 320 321

368 395 420

3. ALTERATION OF GROUND-WATER HYDROLOGY DUE TO SUBSIDENCE

21 165 199 292 299 302 303 305 312 315 319 320
321 395 420

4. ALTERATION OF DRAINAGE

A. RE SUBSIDENCE

21 165 199 299 302 303 312 315 319 320 321 327
338 368 371 373 375 388 395 420

B. RE INDUSTRIAL FACILITY MANAGEMENT

20 21 26 43 62 105 107 111 113 124 127 155
160 165 170 175 176 184 199 217 233 243 262 274
292 310 312 320 368 403 406 408 420 477 538 540
542 548 549 576 585 614

5. RIVER CONTROL AND FLOW MODIFICATION

A. RE SUBSIDENCE

21 199 420

B. RE FRESH-WATER SOURCE FOR POWER PLANT

21 62 105 107 111 127 156 160 170 175 176 199
210 216 233 243 262 274 310 403 576 614

6. CANALIZATION

14 16 25 36 54 62 65 69 70 71 76 81
90 94 102 108 109 110 111 112 113 115 116 121
125 126 127 129 132 137 144 146 147 152 160 169
173 174 175 176 179 180 189 201 202 203 205 214
215 218 219 230 231 233 238 243 243 250 251 252
253 254 255 257 270 284 285 287 292 293 308 310
311 313 317 318 320 323 358 362 366 389 390 391
401 403 405 410 411 412 413 420 431 444 445 449
492 493 496 498 501 507 509 516 517 518 519 545
546 550 576 584 590 592 598 604 614

A. RE FRESH-WATER SOURCE FOR POWER PLANT

21 62 105 107 111 127 156 160 165 170 199 211
216 233 243 262 274

B. RE TRANSPORT OF EFFLUENTS

21 62 105 107 111 113 127 136 155 156 160 165
170 175 176 199 210 211 216 217 229 233 243 262
274 292 310 403 406 408 420 477 538 539 540 542
549 576 614

7. WEATHER MODIFICATION RELATED TO HEAT AND WATER VAPOR DISCHARGE

11 21 36 71 76 81 90 91 94 102 108 109
110 112 115 116 121 123 125 126 127 132 137 144
146 147 152 154 165 170 171 173 174 189 201 203
205 214 215 218 219 230 231 233 238 250 251 252
253 254 256 257 262 264 268 270 285 293 308 310
311 313 318 320 323 362 366 389 390 391 401 405
411 412 413 431 444 445 449 507 509 516 517 518
519 545 546 548 550 584 590 592 593 598

8. IMPERVIOUS SURFACING RE EFFLUENT STORAGE PONDS

14 21 36 59 65 69 70 71 76 81 90 94
102 108 109 110 111 112 115 116 121 125 126 127
132 137 144 146 147 152 165 170 173 174 179 180

189 201 205 214 215 217 218 230 231 233 238 250
251 252 253 254 257 262 270 285 293 308 311 313
318 320 323 362 366 389 390 391 401 405 410 411
412 413 420 431 444 445 449 507 509 516 517 518
519 545 546 549 550 584 590 592 598

9. NOISE AND VIBRATION

10 11 21 34 49 124 165 168 189 215 218 219
265 310 313 324 407 420 457 525 548 572 576 585
594

B. LAND TRANSFORMATION AND CONSTRUCTION

179 180 294

1. URBANIZATION

20 21 40 104 105 107 127 149 157 165 170 199
265 292 294 364 455

2. INDUSTRIAL SITES AND BUILDINGS

10 11 14 18 21 24 28 30 34 36 40 54
60 62 70 76 90 91 94 104 105 107 108 109
110 112 116 121 123 124 125 126 127 130 132 146
149 152 155 156 157 165 170 173 174 175 176 178
179 180 182 184 189 201 205 211 214 215 216 217
218 219 223 224 231 233 238 243 248 250 251 252
253 254 256 257 258 264 265 268 270 274 284 285
287 292 293 294 308 310 311 312 313 318 320 323
362 364 366 389 390 391 401 403 405 406 408 411
412 413 420 431 444 445 449 455 457 477 507 509
516 517 518 519 538 539 540 542 543 545 546 548
549 550 576 584 585 586 590 592 593 594 598 605
609 613 614 717

3. HIGHWAYS

21 104 127 165 199 265 364 407 457 576 594

4. ROADS

292 299 319 320 364 368 407 457 548 576 594

5. TRANSMISSION LINES, PIPELINES AND CORRIDORS

62 155 175 184 233 243 292 299 302 305 310 312
320 321 327 338 352 353 356 364 368 371 373 375
388 395 403 407 420 455 457 477 540 548 576 585
586 593 594 609 613 614

6. BARRIERS INCLUDING FENCING

243 292 299 320 403 407

7. CHANNEL DREDGING AND STRAIGHTENING

62 119 155 169 176 179 180 243 299 306 312 317
320 321 367 375 403 474 498

8. CANALS

62 155 176 243 285 292 299 302 310 312 315 320
321 395 403 420 477 498 538 539 540 542 614

9. DAMS AND IMPOUNDMENTS

62 175 176 184 233 243 285 292 299 302 310 312
315 320 387 395 403 406 420 457 538 539 540 542
548 549 576

10. OFFSHORE STRUCTURES

299 320 368 570

11. BLASTING AND DRILLING

175 216 299 320 368 392 457 495 548 576

12. CUT AND FILL

62 119 175 243 285 292 299 320 368 403 457 548
549 576

C. RESOURCE EXTRACTION

1. WELL DRILLING AND FLUID REMOVAL

14 22 30 36 73 76 89 90 94 96 102 108
109 110 112 114 115 116 121 122 125 126 127 128
129 132 137 144 146 147 152 173 174 184 189 190
201 205 214 215 218 219 230 231 238 239 250 251
252 253 254 255 257 270 276 278 284 285 287 288
293 295 299 302 303 305 308 311 313 318 319 320
321 323 325 326 332 338 362 364 366 368 371 374
387 388 389 390 391 392 395 401 402 404 405 406
408 411 412 413 420 426 431 444 445 449 477 495
507 508 509 516 517 518 519 539 540 542 545 546
548 549 550 562 576 580 581 584 585 590 592 598
603 605 609

D. PROCESSING

1. ENERGY GENERATION (ELECTRICAL)

62 155 175 176 184 216 233 291 294 299 302 303
305 306 310 312 315 319 320 321 327 338 351 364

368 371 373 388 392 395 406 420 477 538 539 540
542 543 548 549 576 585 586 594 603 609 613 614

2. MINERAL PROCESSING

77 184 302 319 320 321 332 364 373 395 406 420
477 540 549 594 609 613

3. CHEMICAL INDUSTRY

77 184 302 319 320 321 332 364 395 406 420 477
538 549 594 609 613

4. GAS REFINING

184 299 302 319 320 321 364 406 477 603

5. PULP AND PAPER

184 233 299 302 319 320 321 364 406 455 477 540
549 609

6. OTHER

77 80 393

E. LAND ALTERATION

1. WASTE CONTROL - SURFACE EXCAVATION FOR STORAGE PONDS

54 62 76 89 90 91 94 110 121 125 126 127
146 147 152 173 174 176 189 201 205 214 215 218
219 231 243 250 251 253 254 257 270 284 285 287
293 299 303 308 311 312 313 318 320 323 362 366

371 389 390 391 401 403 405 411 412 413 420 431
444 445 449 457 507 509 516 517 518 519 545 546
548 549 550 576 584 586 590 592

F. RESOURCE RENEWAL

1. REFORESTATION

A. AFTER CONSTRUCTION AND DURING OPERATION OF GEOTHERMAL FIELD

184 285 299 319 320 321 420 539 540 549 576

B. RECLAMATION OF LAND AFTER LIFE OF GEOTHERMAL FIELD

184 285 299 320 395 549

2. WILDLIFE STOCKING AND MANAGEMENT

A. AFTER CONSTRUCTION AND DURING OPERATION OF GEOTHERMAL FIELD

62 155 184 299 302 319 320 321 368 395 420 549
576

B. RECLAMATION OF LAND AFTER LIFE OF GEOTHERMAL FIELD

184 299 320 395 549

G. CHANGES IN TRANSPORTATION

1. AUTOMOBILE

21 104 165 199 265 299 319 320 364 368 387 407
576 594

2. TRUCKING

21 104 124 165 199 265 299 319 320 368 548 576
594

3. COMMUNICATION

21 104 165 199 299 594

4. PIPELINE

10 11 21 24 28 62 104 118 124 149 155 156
157 160 165 170 171 176 178 182 184 199 210 211
216 217 223 224 229 233 243 258 262 271 274 299
302 303 305 310 312 320 321 327 332 338 351 352
353 364 368 371 373 387 388 395 403 406 408 420
477 540 542 548 570 576 585 586 593 594 609 613
614

H. WASTE EMPLACEMENT AND TREATMENT

14 15 19 22 23 30 50 51 56 57 58 65
69 70 71 73 76 81 86 87 89 90 94 96
102 105 107 108 109 110 112 114 115 115 116 121
122 125 126 127 128 129 132 136 137 144 146 147
151 152 170 173 174 189 190 201 202 203 205 214
215 218 219 230 231 238 239 250 251 252 253 254
255 257 270 275 276 278 284 285 287 288 292 293
295 296 298 308 311 313 318 319 320 321 323 325
326 362 366 389 390 391 401 401 404 405 411 412
413 426 431 433 444 445 449 471 497 501 507 508
509 516 517 518 519 524 538 545 550 562 582 584
590 592 598 605

1. OCEAN DUMPING

38 62 155 156 164 171 176 184 299 302 305 320
321 367 395 406 455 538 540 542 570 586

2. SOLID WASTES

62

3. EMPLACEMENT OF TAILINGS AND SPOIL

16 17 20 21 25 26 43 111 113 124 127 160
165 184 199 243 285 299 320 368 371 403 406 420
477 542 548 549 576

4. JUNK DISPOSAL

21 124 127 138 165 184 199 223 291 299 320 327
338 368 371 406 408 420 477 543 548 593 613

5. DEEP WELL EMPLACEMENT (REINJECTION)

10 11 21 38 124 156 164 165 178 182 184 216
299 305 306 320 321 364 368 371 395 406 408 420
455 477 538 543 548 576 586 609

6. COOLING WATER DISCHARGE

10 11 21 24 62 98 105 107 124 136 138 155
156 164 165 170 171 175 176 184 199 210 211 216
223 224 229 233 248 256 262 274 285 292 299 302
303 310 312 315 320 321 351 352 368 371 395 406
420 477 538 539 540 542 543 548 549 576 585 586
614

7. LIQUID EFFLUENT DISCHARGE (GEOTHERMAL WATER)

10 11 21 24 28 38 86 88 104 105 107 124
130 136 138 149 155 156 157 164 165 170 171 176
178 182 184 191 199 210 211 216 217 223 224 229
240 256 258 274 285 299 302 303 305 306 312 315
319 320 321 327 332 351 352 353 364 368 371 373

387 388 395 406 408 420 455 477 497 504 509 538
539 540 542 543 548 549 576 585 586 593 603 609
613

8. SPENT LUBRICANTS

199 299 320 374 406 408

9. HEAT DISCHARGE

21 62 62 88 98 104 118 130 149 155 156 157
164 165 170 171 175 176 182 191 199 202 203 210
211 216 217 223 224 229 233 233 255 256 258 260
262 264 272 274 291 299 302 303 306 310 312 312
315 320 321 327 351 352 353 362 364 368 371 387
388 395 401 420 455 481 491 509 510 511 512 513
514 515 517 518 519 542 547 576 580 581 585 593
613 614

10. WATER VAPOR DISCHARGE

10 11 21 62 98 156 164 165 170 182 217 223
224 233 248 262 264 291 299 310 315 321 327 368
371 392 420 548

11. OTHER GASEOUS DISCHARGE

10 11 21 28 88 124 138 164 165 170 199 217
223 256 260 264 274 299 319 320 327 368 392 420
506 539 548 576 613

12. DISPOSAL OF PIPELINE PRECIPITATES (SCALING)

21 38 124 138 164 165 184 217 223 224 258 274
291 299 305 306 312 320 332 338 353 364 368 371
373 388 395 406 420 477 542 543 549 585 586 609
613 614

I. CHEMICAL TREATMENT

19 57 69 70 76 90 94 121 122 125 126 127
147 162 174 189 190 201 205 214 215 218 230 231
253 254 257 270 278 284 285 288 293 295 308 311
313 318 319 320 323 325 326 362 366 389 390 391
401 404 405 411 412 413 426 431 444 445 449 507
509 516 517 518 519 545 546 550 584 590 592 598
605

1. BIOCIDES IN COOLING TOWERS

21 124 136 155 156 165 170 184 210 229 233 248
262 264 274 299 310 312 315 320 368 371 395 406
420 477 538 548 609

2. OTHERS

28 124 138 184 223 299 320 586

J. ACCIDENTS

22 30 50 51 56 57 58 65 69 70 71 73
76 81 87 89 90 91 94 96 102 108 109 112
114 115 116 121 122 123 125 126 127 128 129 132
137 144 146 147 151 152 173 174 189 190 201 202
203 205 214 215 218 219 230 231 238 239 250 252
253 254 255 257 270 275 276 278 284 285 287 288
293 295 296 308 311 313 318 319 320 321 323 325
326 362 366 389 390 391 401 404 405 411 412 413
426 431 444 445 449 501 507 508 509 516 517 518
519 545 546 550 562 584 590 592 598 605

1. DRILLING MUDS

21 124 164 165 184 199 299 320 368 371 374 402

406 408 420 455 477 548 549 549 576

2. BLOWOUTS

10 11 21 38 98 124 155 164 165 171 184 199
210 211 216 240 274 299 302 303 305 319 320 321
368 371 395 406 408 420 455 477 539 540 542 548
549 549 576 585 609

3. PIPELINES

10 11 21 28 38 62 98 104 124 130 149 155
155 156 160 164 165 170 171 175 176 184 199 210
211 216 216 217 223 224 229 233 240 258 274 299
302 303 305 310 312 319 320 321 327 368 371 373
375 388 395 406 408 420 434 435 455 477 506 538
539 540 542 543 548 549 549 576 585 586 593 609
613 614

4. POWER PLANT

10 11 21 28 38 62 98 104 124 136 138 155
155 156 164 165 170 171 175 176 182 184 199 210
211 216 217 223 224 229 233 240 256 262 264 272
274 291 299 302 303 305 310 312 315 319 320 321
327 364 368 371 388 395 406 408 420 477 506 538
539 540 542 543 548 549 549 576 585 586 609 613
614

5. STORAGE PONDS

21 38 62 98 105 107 124 136 155 155 156 164
165 170 176 184 199 210 211 216 217 224 229 233
240 262 274 299 302 303 305 310 312 315 319 320
321 368 395 406 408 420 455 477 538 539 540 542
548 549 549 576 609

6. CANALS

21 38 62 98 113 136 155 155 156 160 164 165
170 176 184 199 210 211 229 233 240 243 262 274
292 299 302 303 305 310 312 315 319 320 321 395
406 408 420 455 477 538 539 540 542 549 549 609
614

7. OPERATIONAL FAILURE

10 11 21 28 38 62 98 124 136 138 155 156
164 165 170 171 175 176 184 199 210 211 216 217
223 229 233 240 274 299 302 303 310 312 315 319
320 321 327 338 368 371 373 388 395 406 408 420
477 538 539 540 542 543 548 549 576 585 586 609

V. INSTITUTIONAL ANALYSIS OF GEOPRESSURED-GEOTHERMAL DEVELOPMENT

10 11 40 576 583

A. LOCAL LAWS AND REGULATIONS

164 310 315 371 420 548

B. STATE LAWS AND REGULATIONS

5 142 153 163 164 208 209 246 247 310 315 339
345 371 420 452 502 503 520 521 536 537 548 576
579

C. FEDERAL LAWS AND REGULATIONS

5 142 153 163 164 166 208 209 213 221 310 315
371 400 415 417 420 536 548 565 566 567 568 569
570 571 572 576 579

D. ROLE OF PUBLIC LANDS

5 142 163 207 213 565 566 567 568 569 570 571
572 579

E. LAND USE MANAGEMENT

5 10 11 40 62 67 104 111 119 127 155 175
176 182 184 185 187 198 216 224 233 243 258 265
274 285 290 291 292 294 299 302 305 306 310 312
315 319 320 321 327 332 334 335 336 338 351 352
353 354 355 356 364 368 371 376 377 387 388 392
395 403 406 407 408 420 455 457 477 495 498 540
542 543 547 548 549 569 570 572 576 580 581 585
586 593 594 603 609 613 614

F. POLITICS

5 21 40 88 104 124 164 217 315 371 420

G. ENERGY CONSERVATION

104 156 165 191 233 310 351 352 353 387 408 455

VI. DATA FOR SPECIFIC TEST WELL SITES

(SEE OTHER ENTRIES FOR SPECIFIC SUBJECTS)

164 436 437 552

VII. BIBLIOGRAPHIES (SEE ALSO II E 13)

127 320 321 322 404 523

APPENDIX G

Research scientists and/or institutions with expertise on the Louisiana-Texas coastal region and/or geothermal energy. Names and addresses are listed first, then the telephone number in parentheses, then area(s) of expertise.

Robert (Bob) Adams, Science Research Center, Box 1095, Graver, Texas 79040 (806-733-2202)

botany; endangered plant species; developed computer ecological data retrieval system for endangered species of Colorado

Steven O. Andersen, College of the Atlantic, Bar Harbor, Maine; Environmental Law Institute, Energy Section, Washington, D.C., (202-452-9600)

environmental impact of exploitation of geothermal resources; geothermal land use problems; economics of energy resources

Art Anderson, U.S. Fish and Wildlife Service, Suite 24, Commerce 1, 4455 South Padre Island Drive, Corpus Christi, Texas 78411

review of environmental permits for energy industrial activities in the Texas coastal region

David Anderson (also: Ronald Doctor), State Energy Commission, 1111 Howe Ave., Sacramento, California 95814 (916-322-6476)

planning geothermal activities in California

Lynn Anspaugh, Joyce Plis (secretary), Biomedical and Environmental Research Division, Lawrence Livermore Laboratory, University of California, P. O. Box 808, L-523, Livermore, California 94550 (415-447-1000)

environmental impact of geothermal activities in Imperial Valley, California; radionuclide emissions

Aransas National Wildlife Refuge, Frank Johnson, Ken Batts, Charles Ward, P. O. Box 68, Austwell, Texas 77950 (512-286-3559)

Whooping Crane - *Grus americana*

Neil E. Armstrong, Dept. of Civil Engineering, Ernest Cockrell Jr. Hall
8.608, University of Texas, Austin, Texas 78712 (512-471-5602)

coastal ecology and energetics; nutrient cycling in coastal ecosystems

K. A. Arnold, Dept. of Wildlife Sciences, Texas A&M University,
College Station, Texas 77840

birds including Texas' endangered species

Saul Aronow, Professor of Geology, Lamar University, Beaumont,
Texas (713-838-8913)

geology of east Texas

Association of Systematics Collections, Rebecca Pyles, ASC Registry,
Museum of the High Plains, Fort Hays State University, Hays,
Kansas 67601 (913-864-4867)

reference service of specialists on different groups of plants and animals relating to environmental studies

Leonard Bahr, Center for Wetland Resources, Louisiana State University,
Baton Rouge, Louisiana 70803 (504-388-1558)

marine and estuarine ecology, Louisiana

James Barkuloo, U.S. Fish and Wildlife Service, 17 Executive Park
Drive, N. E., Atlanta, Georgia 30329 (404-769-5430)

coastal ecosystems

Bruce Barron, California Division of Oil and Gas, Long Beach Office,
5199 E. Pacific Coast Hwy., Long Beach, California 90804

oil well research

Don Bebout (also V. Gavenda, S. Claypool, J. H. Haw, J. H. Seo),
Bureau of Economic Geology, University of Texas, P. O. Box X,
Austin, Texas 78712 (512-471-1534)

projector director, geological aspects and resource assessment and site selection studies- geopressured-geothermal energy, Texas Gulf Coast

Jerry Bently, Federal Building, 300 East 8th, Austin, Texas 78701 (512-397-5434)

Texas' endangered species;
Ross' Goose - *Chen rossi*
Eskimo Curlew - *Numenius borealis*

Biology Library, Betty White, Librarian, Patterson Laboratories, University of Texas, Austin, Texas 78712 (512-471-1475)

Ron Bisbee or Jim Neaville, Brazoria and San Bernard National Wildlife Refuges, P. O. Box 1088, Angleton, Texas 77515 (713-849-6062)

management of Brazoria and San Bernard, National Wildlife Refuges

Gene Blacklock, Welder Wildlife Refuge, Sinton, Texas (512-364-2643)

wildlife library sources; natural history, botany, ornithology;
Olivaceous Cormorant - *Phalacrocorax olivaceus*
Fulvous Tree Duck - *Dendrocygna bicolor*
Masked Duck - *Oxyrua (Erismatura) dominica*
White-tailed Kite - *Elanus leucurus*
Swallow - tailed Kite - *Elanoides forficatus*
Gray Hawk - *Buteo nitidus*
White-tailed Hawk - *Buteo albicaudatus*
Jacana - *Jacana spinosa*
American Oystercatcher - *Haematopus palliatus*
Botteri's Sparrow - *Aimophila botteri*

W. F. Blair, Dept. of Zoology, University of Texas, Austin, Texas 78712 (512-471-3163)

ecology and vertebrate zoology

Dan Boon, 10 Parks and Wildlife Drive, Port Arthur, 77640

American Alligator - *Alligator mississippiensis*

Walter Baynton, Hallowing Point Field Station, Center for Environmental and Estuarine Studies, University of Maryland, Prince Frederick, M. D. 20678 (301-326-4281)

estuarine and marine ecology and productivity; impacts of coastal energy conversion facilities

Bill Brogden, University of Texas, Port Aransas Marine Lab., Port Aransas, Texas 78373 (512-749-6711)

marine ecology; life history computer data bank

Bryce Brown, Dept. of Biology, Baylor University, Waco, Texas

Giant Toad - Bufo marinus

Lauren E. Brown, Dept. of Biological Sciences, Illinois State University, Normal, Illinois 61761

Houston Toad - Bufo houstonensis

Sandra Brown, Dept. of Environmental Engineering Sciences, University of Florida, Gainesville, Florida (904-392-2428)

ecology of cypress communities; ecological energetics

W. C. (Bill) Brownlee, Texas Parts and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744 (512-475-4971)

birds, Attwater's Prairie Chicken - Tympanuchus cupido

Bureau of Economic Geology, University of Texas, P. O. Box X, Austin, Texas 78712 (512-471-1534)

Texas geology; research on geopressured-geothermal energy resources; geological and environmental mapping; see also D. Bebout, R. Gregory, T. C. Gustavson, C. Kreitler, B. Loucks, L. McCarley, M. McGraw, L. T. McKinney, M. Moseley, M. Tandy, B. White

Patrick R. Burke, Texas Parks and Wildlife Dept., Comprehensive Planning Branch, 4200 Smith School Road, Austin, Texas 78744 (512-475-4991)

Ted Callender, U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, Virginia 22092

geochemistry of geopressured water

Archie Carr, Florida State Museum, University of Florida, Gainesville, Florida

sea turtles:
Loggerhead Turtle - *Caretta caretta*
Green Turtle - *Chelonia mydas*
Leatherback Turtle - *Dermochelys coriacea*
Hawksbill Turtle - *Eretmochelys imbricata*
Ridley Turtle - *Lepidochelys kempi*

Center for Energy Studies, University of Texas at Austin, Austin, Texas 78712 (512-471-7792)

geopressured studies including: engineering, legal, economic, bibliographic

Phil Chambers, California State Energy Commission, 1111 Howe Ave., Sacramento, California 95814

geothermal operations in California

Seeling Chang, Conservation Division, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025 (415-323-8111)

federal leasing decisions

Robert L. Christiansen, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025 (415-323-8111 Ext. 2680)

U.S. Geological Survey geothermal research

Bob Clark, General Land Office of Texas, Stephen F. Austin Bldg. 636, Austin, Texas 78701 (512-475-4411)

permitting for energy exploitation activities on Texas coastal public lands; impacts of activities in coastal ecosystems

Harry Coulombe, National Western Energy and Land Use Team, Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Room 206, Federal Building, Ft. Collins, Colorado 80521 (303-221-0930)

research manager, oil shale impact

Max Critendon, Chairman, Geothermal Environmental Advisory Panel,
U.S. Geological Survey, 345 Middlefield Rd., Menlo Park,
California 94025 (415-323-8111)

U.S.G.S. geothermal environmental matters

Armando de la Cruz, Mississippi State University, Starkeville,
Mississippi (601-325-5722)

ecology and biological energetics

Kaye Culbertson, c/o. Dr. D. J. Schmidley, Dept. of Wildlife Sciences,
Texas A&M University, College Station, Texas 77840

mammals - life history and status; general coastal fauna

Rich Curtin, Offshore Operations Engineer, State of California Resources
Agency, Department of Conservation, Division of Oil and Gas,
5199 East Pacific Coast Highway, Suite 309-N, Long Beach,
California 90804 (213-390-5311)

fluid injection

Sally Davenport (also Art Eatman), Texas Coastal and Marine Council,
State Library Building, Austin, Texas (512-475-5849)

coastal hazards (particularly hurricanes)

John Day, Center for Wetland Resources, Louisiana State University,
Baton Rouge, Louisiana 70803 (504-388-1558)

estuarine and marine ecology and energetics--especially Louisiana

Robert Dennie, Information Officer, Louisiana Wildlife and Fisheries
Commission, 400 Royal Street, New Orleans, Louisiana
(504-527-5126)

James R. Dixon, Dept. of Wildlife Sciences, Texas A&M University,
College Station, Texas 77843

reptiles and amphibians

Ronald Doctor (see also: David Anderson), State Energy Commission,
1111 Howe Ave., Sacramento, California 95814 (916-322-6476)

geothermal activities in California

Environmental Systems and Service, A Division of M. P. Sperling Corp., 4895 Gaddy Lane, P. O. Box 188, Kellseyville, California 95451 (707-263-5122)

noise and vibration; spills and leaks; ambient source testing

Donald Everetts, Manager of Energy and Metal Resources, State Lands Commission, California State Land Division, Sacramento, California 95814 (916-322-3690)

geothermal operations in California

Fish and Wildlife Reference Service, Marsha Fralick, Denver Public Library, 2100 West Mississippi Avenue, Denver, Colorado 80223, (303-922-0505, 303-573-5152 ext. 266)

state fish and wildlife research index. Literature search and computer print-out of bibliographic materials

Carl Fleming, Big Thicket National Preserve, U.S. National Park Service, Beaumont, Texas (713-838-0271)

Dick Forrester, California Fish and Game Commission, 1416 9th St., Sacramento, California 95814 (916-445-1383)

impacts of California geothermal operations on fish and wildlife

Carl Frentress, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744 (512-475-4971)

remote sensing data of wildlife resources-habitat mapping

Roy Frye, Texas Parks and Wildlife Dept., 4200 Smith School Road, Austin, Texas 78744 (512-475-6583)

habitat mapping

Robert K. Gabrysch, U.S. Geological Survey, 2320 La Branch Street, Room 1112, Houston, Texas 77004

F. R. Gehlbash, Dept. of Biology, Baylor University, Waco, Texas 76706

Texas' endangered species

Martha Gilliland, Energy Policy Studies, Inc., El Paso, Texas
(915-581-1707)

ecology and biological energetics; energy policy questions

Donald B. Gilmore, geologist, U.S. Environmental Protection Agency,
Office of Research and Development, Environmental Monitoring
and Support Laboratory, P. O. Box 15027, Las Vegas, Nevada
89114 (702-736-2969)

monitoring environmental effects of geothermal resource exploitation; geothermal electric conversion; geothermal waste disposal

Gill Gilmore, P. O. Box 164, Seadrift, Texas 77983 (512-785-3521)

remote sensing data on coastal ecosystems

Dena Gordon, Texas Dept. of Water Resources Library, SFA Bldg.,
Room 511, 1700 N. Congress, Austin, Texas 78711 (512-475-3781)

computer literature searches

James G. Gosselink, Dept. of Marine Sciences, Center for Wetland
Resources, Louisiana State University, Baton Rouge, Louisiana
70803 (504-388-3202)

estuarine and marine ecology and biological energetics--particularly Louisiana; impacts of man's activities in estuarine ecosystems

Governor's Budget and Planning Office, State of Texas, Austin, Texas
(512-475-2427)

list of environmental impact statements for projects in Texas

A. Ray Gregory, Bureau of Economic Geology, University of Texas,
P.O. Box X, Austin, Texas 78712 (512-471-1534)

engineering assessement of Frio test well sites, geopressured-geothermal energy, Texas Gulf Coast

Wayne Gueswel, see U.S. Fish and Wildlife Service Office of Endangered Species

Pete Gunter, Professor of Philosophy, North Texas State University, Denton, Texas

the Big Thicket area of east Texas

Thomas C. Gustavson, Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

geological and environmental aspects of geopressured-geothermal resources

Charles A.S. Hall, Dept. of Ecology and Systematics, Cornell University, Ithaca, New York (607-256-4522)

ecology, energy and systems analysis of coastal areas

Roy Hamrick, Professor of Journalism, University of Texas at Arlington, Arlington, Texas

photography of the Big Thicket area of east Texas

Paul Harcombe, Dept. of Biology, Rice University, Houston, Texas, or Rice Center for Community Design and Research, 400 Parkway Tower, 1929 Allen Parkway, Houston, Texas 77019 (713-529-7672)

plant community ecology of the central Texas coast -particularly Chambers County

Jeff Hargis, Production Manager, General Crude Oil Corp., P.O. Box 2252, Houston, Texas 77001 (713-651-9261)

management of oil field production for General Crude Oil Corp. including the Saratoga oil field in Hardin Co.

James Harman (see also: Richard Mitchell), County Counsel, Imperial County, 940 Main St., El Centro, California 92243 (714-352-3610)

planning and legal aspects of geothermal operating for county government in Imperial Valley, California

Richard Harrell, Professor of Biology, Lamar University, Beaumont, Texas (713-838-8913)

aquatic ecology of the upper Texas coast; industrial pollution in east Texas

Peggy Harwood, Texas General Land Office, Planning Division (Coastal Management Program), 1700 N. Congress Ave., Austin, Texas (512-475-6902)

Texas coastal management; geology; natural coastal hazards; remote sensing studies of the Texas coastal region

Hamilton Hess, c/o Sierra Club Research Department, 530 Bush Street, San Francisco, California 94108 (415-981-8634)

environmental impact of geothermal operations

David Hill, Energy Resources Conservation and Development Commission, 1111 Howe Ave., Sacramento, California 95814 (916-322-6476)

geothermal operations in California

Bill Hoffman, Energy section, Texas Dept. of Water Resources, Stephen F. Austin Building, 1700 N. Congress, Austin, Texas 78701 (512-475-3187)

energy-related water exploitation in Texas

Clark Hubbs, Dept. of Zoology, University of Texas, Austin, Texas 78712 (512-471-1176)

ichthyology and aquatic ecology; Texas' endangered fish species; aquatic environmental problems

Wallace Huey, Offshore Operations Engineer, State of California Resources Agency, Department of Conservation, Division of Oil and Gas, 5199 East Pacific Coast Highway, Suite 309-N, Long Beach, California 90804 (213-390-5311)

subsidence

Institute of Ecology, 1315 16th Street, N. W., Washington D. C., 20036 (202-332-1712)

research and publication on ecological topics

Institute of Ecology, E. P. Odum, University of Georgia, Athens, Georgia (404-542-3310)

ecological research; systems approaches to environmental impact analysis

Pauline James, Dept. of Biology, Pan American University, Edinburg, Texas (512-381-3161)

Ringed Kingfisher - Megaceryle torquata
White-collared Seedeater - Sporophila torqueola
Giant Toad - Bufo marinus

Donald F. Johnson, Lake County Planning Department, Lakeport, California 95453

conference on environmental consequences of geothermal development-Konocti Harbor

James B. Johnston, National Coastal Ecosystem Team, Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, National Space Technology Laboratory, Bay St. Louis, Mississippi 39520 (601-688-2091)

ecology of southern Louisiana and the upper Texas coast

Marshall Johnston, Department of Botany (also Rare Plant Study Center), University of Texas, Austin, Texas 78712 (512-471-4327)

systematic botany - particularly the flora of Texas and surrounding states

Maxine Johnston, Big Thicket National Preserve, U.S. National Park Service, Beaumont, Texas (713-838-0271)

the Big Thicket region of east Texas

Carol Justice, see U.S. Fish and Wildlife Service, Office of Endangered Species

Bob Kemp, Texas Parks and Wildlife Dept., Fisheries Division, 4200 Smith School Road , Austin, Texas 78744 (512-475-4939)

Steve Kennedy, T.O.E.S. (Texas Organization for Endangered Species), Box 12773, Austin, Texas 78711, or General Land Office, Stephen F. Austin Bldg., Austin, Texas 78701 (512-475-6902)

Chairman - TOES Animal Committee; corresponding Secretary-TOES;
birds, Roseate Spoonbill - Ajaia ajaja
Sooty Tern - Sterna fuocata

Yousif Kharaka, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025 (415-323-8111)

geochemistry of geopressured water

B. D. King, Texas Parks and Wildlife Department, Environmental Division, 4200 Smith School Road, Austin, Texas 78744 (512-475-4888)

Kirk King, Patuxent Wildlife Research Center, Gulf Coast Field Station, P.O. Box 2506, Victoria, Texas 77901 (512-573-2111)

birds,
White-faced Ibis - Plegadis chihi
Brown Pelican

James Kirkwood, U.S. Fish and Wildlife Service, 17 Executive Park Drive, N. E., Atlanta, Georgia 30329 (404-526-4457)

coastal ecosystems

Wallace Klussman, Wildlife Specialist and Sea Grant Leader, Texas A&M University, College Station, Texas (713-845-7471)

Charles Kreitler, Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

groundwater geochemistry and fault and fracture systems of the Texas Gulf Coast

Don Lande, Offshore Operations Engineer, State of California Resources Agency, Department of Conservation, Division of Oil and Gas, 5199 East Pacific Coast Highway, Suite 309-N, Long Beach, California 90804 (213-390-5311)

geothermal operations in California

Signe Larsen, Reference Section, U.S. Department of the Interior Library, Washington, D. C. (202-343-3896)

David Layton, Biomedical and Environmental Research Division, Lawrence Livermore Laboratory, University of California, P.O. Box 808, Livermore, California 94550 (415-447-1000)

integrated assessment, water resources questions of geothermal exploitation in Imperial Valley, California

G. W. Ledingham, Offshore Operations Engineer, State of California Resources Agency, Department of Conservation, Division of Oil and Gas, 5199 East Pacific Coast Highway, Suite 309-N, Long Beach, California 90804 (213-390-5311)

California oil and gas field operations, subsidence

Melvin Lehman, Environmental Science and Engineering, Inc., 14220 Newberry Rd., Gainesville, Florida (904-372-3318)

oyster reefs; estuarine and marine ecology; Crystal River project, Florida; environmental impact of coastal projects; biological energetics

Philip Leitner, Biology Department, St. Mary's College, Moraga, California 94575 (415-376-4411 Ext. 365)

environmental impact of noise from geothermal operations

Life History Data Bank, Texas Natural Resources Information System, T. R. Evans, Texas Department of Water Resources, Stephen F. Austin Building, Austin, Texas (512-475-2661)

computer-retrievable data file containing extensive biological and ecological information on coastal organisms; system developed by Brogden, Oppenheimer, et. al.

Gene E. Likens, Dept. of Ecology and Systematics, Cornell University, Ithaca, New York (607-256-4631)

ecology and biological energetics; biological carbon problems including carbon dioxide

Don Lollock, California Fish and Game Commission, 1416 9th St., Sacramento, California 95814 (916-445-1383)

impacts of California geothermal operations on fish and wildlife

Bob Loucks (also Marianne Moseley, Turner Williamson), Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

sandstone consolidation studies, Frio and Wilcox Formations, geopressured-geothermal energy development, Texas Gulf Coast

A. E. Lugo, Center for Wetlands and Dept. of Botany, University of Florida, Gainesville, Florida (904-392-2424, 904-392-1486) (Botany)

Lyle, John T., Graduate Coordinator, Landscape Architecture Department, School of Environmental Design, California State Polytechnic University, Pomona, 3801 West Temple Avenue, Pomona, California 91768 (714-598-4188)

environmental impact analysis; planning for minimal environmental impact analysis

Bill Mahler, Curator of the Herbarium, Barney Lipscombe, Assistant Curator, Southern Methodist University, Dallas, Texas 75222 (214-692-2257)

substantial collections and data on rare and endangered plants of Texas

Philip Malnassy, Professor of Biology, Lamar University, Beaumont, Texas (713-838-8913)

flora of the Big Thicket region of east Texas

Robert F. Martin, Texas Memorial Museum, University of Texas, Austin, Texas 78712 (512-471-5302, 512-471-1604)

reptiles and amphibians

Jerry B. Matthews, Plan energy, 7701 N. Lamar, Austin, Texas (512-458-5315)

computer literature retrieval systems; bibliographies on geopressured-geothermal topics

Lon McCarley, Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

geophysics of the Wilcox Formation, geopressured energy resources, Texas

Cindy McCauley, Librarian, National Power Plant Team, Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Great Lake Fisheries Laboratory, 1451 Green Road, Ann Arbor, Michigan 48105 (313-994-3331)

Maryann M. McGraw, Bureau of Economic Geology, University of Texas,
P.O. Box X, Austin, Texas 78712 (512-471-1534)

geological and environmental aspects of geopressured-geothermal resources

Henry W. McKellar, Belle Baruch Inst. of Marine Fisheries, Columbia,
South Carolina 29208 (803-777-6994)

estuarine and marine ecology; environmental impact of coastal projects (particularly power plants); biological energetics; Crystal River Project, Florida

Lloyd Tony McKinney, Bureau of Economic Geology, University of Texas,
P.O. Box X, Austin, Texas (512-471-1534)

Texas flora

Craig A. McMahan, Texas Parks and Wildlife Dept., 4200 Smith School
Road, Austin, Texas 78744 (512-475-4287)

habitat mapping

Gary Meneghin (also: Don Price), Pacific Gas and Electric Company,
3400 Crow Canyon Road, San Ramon, California 94106
(415-820-2000 Ext. 281)

environmental impacts of Geysers geothermal steam field on fish and wildlife

Richard Mitchell (see also: James Harman) Planning Director, Imperial
County Offices, 940 Main Street, El Centro, California 92243
(714-352-8184)

geothermal planning in Imperial County, California

John Moran, Comprehensive Planning Branch, Texas Parks and Wildlife
Dept., 4200 Smith School Rd., Austin, Texas 78744 (512-475-4991)

John Montanari, Project Leader, National Wetlands Inventory, Office of
Biological Services, U.S. Fish and Wildlife Service, Department of
the Interior, Washington D.C. 20240

wetlands classification; habitat characterization

Tom Moore, Texas Parks and Wildlife Dept., Coastal Fisheries Division, 4200 Smith School Road, Austin, Texas 78744 (512-475-4835)

Moseley Marianne, Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

sandstone consolidation studies, Frio and Wilcox Formations, geopressure-geothermal energy development, Texas Gulf Coast

P.E. Muehlberg, Dow Chemical U.S.A., Texas Division, Freeport, Texas 77541

environmental assessment of geopressured energy systems

T. N. Narasimhan, 933 Kains Avenue #1, Albany, California 94706

hydrologeology; subsidence, well testing, numerical modelling, saturated and unsaturated flow of ground water

National Academy of Sciences, 2101 Constitution Ave., Washington, D.C. 20418 (202-393-8100), Environmental Studies Board (202-389-6917, 202-389-6864)

publications on a wide variety of topics including environmental impact

National Conference of State Legislators, 1405 Curtis St., 23rd floor, Denver, Colorado 80202

geothermal resources in the western United States

National Marine Fishery Service, U.S. Department of Commerce, 515 Rusk Street, Houston, Texas 77002 (713-226-5936)

Walter Nichols, Saratoga, Texas

history of oil field operations in the Saratoga region (former employee of General Crude Oil Corp. who has lived in the Saratoga area for 30 years)

Eugene P. Odum, Institute of Ecology, University of Georgia, Athens, Georgia (404-542-3310)

systems, estuarine, and bioenergetics ecology; environmental impact analysis

H. T. Odum (Joan Breeze, Secretary) (also: Martha Gilliland, Sandra Brown, W. Michael Kemp, Maurice Sell, Melvin Lehman), Dept. of Environmental Engineering Sciences, University of Florida, Gainesville, Florida (904-392-0847)

biological energetics; estuarine and marine ecology (particularly Texas); systems analysis of environmental impact of energy and other industrial projects

C. H. Oppenheimer, University of Texas, Port Aransas Marine Laboratory, Port Aransas, Texas 78373 (512-749-6711)

impacts of coastal projects; marine microbiology and ecology; coastal habitat mapping

Dan Otte, Philadelphia Academy of Sciences (Acad. of Natl. Sci.), Philadelphia, Pennsylvania (215-299-1000)

Orthoptera (including Texas); insect behavior and systematics

Faust Parker, University of Texas, Port Aransas Marine Laboratory, Port Aransas, Texas 78373 (512-749-6711, 512-749-6357)

impacts of geopressured-geothermal energy exploitation on marine ecosystems; effects of sublethal stress on fishes

Edgar Pash, National Western Energy and Land Use Team, Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Room 206, Federal Building, Ft. Collins, Colorado 80521 (303-221-2040)

research manager, geothermal energy

Rich Paul, Audubon Society, c/o Sandy Sprant, Tavemier, Florida, (305-852-5092)

fish eating birds, Reddish Egret - Dichromanassa rufescens

Emil Pawlik, District Engineer, General Crude Oil Corp., Saratoga, Texas (713-258-2646)

water analyses of oil field brines in the Saratoga region of east Texas

Milos R. Pevovic, Bulevar AVNOJ-a III, ulaz 2, stan 27, 11070 Novi Beograd, Yugoslavia

implementation of computer-based analysis and planning re environmental impact using system developed by Lyle et. al. of Cal. Poly. University

Floyd E. Potter, Jr., Texas Parks and Wildlife Department, Region 6 Field Office, 6120 Hwy. 290 West, Austin, Texas 78746 (512-475-4971, 512-288-2697)

nongame wildlife investigations in Texas; endangered species of animals:
Houston Toad - Bufo houstonensis
Black-striped Snake - Coniophanes imperialis
Speckled Racer - Drymobius margaritiferus
Texas Cat-eyed Snake - Leptodeira septentrionalis
Smooth Green Snake - Opheodrys vernalis

Jeff Potter, Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

geophysics of geopressured-geothermal test wells in the Frio Formation, Texas

Gary Powell, Biologist, Texas Dept. of Water Resources, Stephen F. Austin Bldg. 342, 1700 N. Congress, Austin, Texas (512-475-3187, 512-475-4344)

environmental impacts on aquatic organisms; ecology of water exploitation activities

Rebecca Pyles, Association of Systematics Collections, Museum of the High Plains, Fort Hays State University, Hays, Kansas 67601 (913-864-4867)

J. J. Ramsey, Professor of Biology, Lamar University, Beaumont, Texas (713-838-8913)

ornithology (birds)

Rare Plant Study Center, Marshall Johnston, Anders Saustrup, P.O. Box 8495, University of Texas, Austin, Texas 78712 (512-471-3535)

rare and endangered plants of Texas and nearby areas

Research and Planning Consultants, Rod Jackson, Bill Longley, Bruce Snyder, Mills Tandy, 314 West 11th Street, Austin, Texas (512-472-7765), 1705 Guadalupe Street, Austin, Texas (512-472-3675)

impact of oil and gas operation in the Texas coastal zone; coastal zone management; impacts of geopressured operations

Rice Institute of Public Affairs, Rice University, Houston, Texas

inventory of ecosystems of Chambers County, Texas

Jim Riggs, Texas Outdoor Recreation Plan, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744

David Riskind, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744 (512-475-4848)

rare and endangered plants of Texas and nearby areas

David E. Robertson, Battelle Pacific Northwest Laboratories, Battelle Boulevard, Richland, Washington 99352 (Telex 32-6345, 509-942-5664)

gaseous and liquid geothermal pollutants; the Geysers geothermal steam field, California; Cerro Prieto geothermal operations, Baja, Ca., Mexico; chemical characterization studies of geothermal test wells and pilot facilities; chemical species from a geopressured well at Vermillion Bay, Louisiana; environmental impact of geopressured-geothermal resources of the Gulf coast

Rockport Marine Laboratory, Texas Parks and Wildlife Department, Rockport, Texas

biological effects of oil field brines

Anders Saustrup, Rare Plant Study Center, University of Texas, P.O. Box 8495, Austin, Texas 78712 (512-471-3535)

care and endangered plant species

David Schmidley, Dept. of Wildlife Sciences, Texas A&M University, College Station, Texas 77840 (713-845-6751)

mammals - life history and status

B. P. Shephard, Dow Chemical U.S.A., Texas Division, Freeport,
Texas 77541

environmental assessment of geopressured energy system

Wayne Shifflett, Attwater Prairie Chicken National Wildlife Refuge,
P. O. Box 845, Eagle Lake, Texas 77434 (713-234-3021)

Attwater's Prairie Chicken - *Tympanuchus cupido*

Joe (J. H.) Shinn, Biomedical and Environmental Research Division,
Lawrence Livermore Laboratory, P. O. Box 808, Livermore,
California 94550 (415-447-1101)

air pollution, deposition associated with geothermal operations in Imperial Valley, California

Sierra Club Research Department, 530 Bush Street, San Francisco,
California 94108 (415-981-8634)

library on environmental effects of geothermal exploitation, especially in California

Nova J. Silvy, Dept. of Wildlife Sciences, Texas A&M University,
College Station, Texas 77840

Texas' endangered species

Ernest Simmons, Texas Parks and Wildlife Dept., Inland Fisheries
Division, 4200 Smith School Road, Austin, Texas 78744
(512-475-4931)

A. Richard Smith, 6010 Elm St., Houston, Texas 77081 (713-665-1035)

environmental management of brines associated with the Texas sulfur industry

John Smith, Texas Parks and Wildlife Dept., 715 S. Bronte, Rockport,
Texas 78382 (Tex-An 820-1100,512-729-2315)

birds: Brown Pelican - *Pelecanus occidentalis*
Bald Eagle - *Haliaeetus leucocephalus*
Golden Eagle - *Aquila chrysaetos*
Osprey - *Pandion haliaetus*
Peregrine - *Falco peregrinus*
reptiles and amphibians: Houston Toad - *Bufo houstonensis*
American Alligator - *Alligator mississipiensis*

Wade H. B Smith, Mitre Corporation, McLean, Virginia 22101
(703-827-6883)

estuarine and marine ecology; environmental impact of coastal projects (particularly thermal discharges); biological energetics Crystal River Project, Florida

Sam C. Snedaker, University of Miami, Miami, Florida (305-665-9854)

estuarine and marine bioenergetics; environmental impact of energy facilities in coastal regions

W. M. Spaulding, Jr., Geothermal Environmental Advisor, U.S. Fish and Wildlife Service, Department of the Interior, 2800 Cottage Way, Sacramento, Ca. 95825 (916-484-4657)

federal geothermal environmental matters

Doug Stockton, Division of Oil and Gas, State Resources Agency, Sacramento, California 95814 (916-445-9686) hrs 7:35-4:30

management of geothermal industrial operations in California

Reed Stone, Conservation Division, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025 (415-323-8111)

federal geothermal leasing decisions

Howard Tait, National Coastal Ecosystem Team, Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, National Space Technology Laboratory, Bay St. Louis, Mississippi 39520

team leader - N.C.E.T.

Mills Tandy, Research and Planning Consultants, 1705 Guadalupe, Austin, Texas (512-472-7765) Department of Zoology, University of Texas, Austin, Texas 78712 (512-471-4431) Bureau of Economic Geology, University of Texas, P.O. Box X, Austin, Texas 78712 (512-471-1534)

environmental impact of geothermal and geopressured-geothermal operations; ecology, distribution, behavior and systematics of vertebrate animals; coastal management and impact analysis

Texas Department of Highways and Public Transportation, State of Texas, 11th and Brazos Streets, Austin, Texas (512-475-2081)

environmental impact statements relating to the Texas intracoastal waterway

Texas Department of Water Resources, T. R. Evans, Sandra Page, Gary Powell, Stephen F. Austin Bldg. 346, 1700 N. Congress, Austin, Texas 78711 (512-475-4344)

Texas Department of Water Resources Library, Wicky Sleight, head librarian, Wanda Kurio, staff, Stephen F. Austin Bldg. 511, 1700 N. Congress, Austin, Texas 78711 (512-475-3781)

depository for all NTIS documents cited in this report and others

Texas Fish-eating Bird Survey, c/o Steve Kennedy, General Land Office of Texas, Stephen F. Austin Building, 1700 N. Congress, Austin, Texas 78711 (512-475-5851)

annual survey of populations of fish-eating birds on the Texas coast; includes work of S. Kennedy, K. King, G. Blacklock, D. Slack, R. Paul and J. Smith

Texas Memorial Museum, University of Texas, Austin, Texas 78712 (512-471-1604)

extensive natural history collections of fauna, geology, and anthropology including the coastal zone of Texas and Louisiana

Texas Natural Resource Information System, (TNRIS), System General, C. R. Baskin, T. R. Evans, Ruben Sanchez, John Wilson, Texas Dept. of Water Resources, Stephen F. Austin Bldg. 340, 1700 N. Congress, Austin, Texas 78711 (512-475-5851)

computer catalog of water-oriented data including the Life History Data Bank on coastal organisms developed by Brogden, Oppenheimer, et. al.

Texas Organization for Endangered Species, T.O.E.S., P.O. Box 12773, Austin, Texas 78711

Texas' endangered species

Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744

see Burke, Frentress, Frye, Kemp, King, McMahan, Moore, Potter, Riskind, Simmons, Smith

Texas State Library, Barbara Duke, State of Texas, Austin, Texas (512-475-2996)

depository for some NTIS documents--principally on demographic topics

Robert A. Thomas, Dept. of Biochemistry, Louisiana State University Medical Center, 1542 Tulane Ave., New Orleans, La. 70112

reptiles and amphibians
Houston Toad - Bufo houstonensis

Gary A. Tompkins, Biomedical and Environmental Research Division, Lawrence Livermore Laboratory, University of California, P.O. Box 808, Livermore, California 94550 (415-447-1101 Ext. 3456)

soil/plant relationships, heavy metal biocycling; impacts of geothermal operations in Imperial Valley, California

Novena Travis, Texas System of Natural Laboratories, 313 Littlefield Bldg., Austin, Texas 78701 (512-477-4925, 512-477-4934, 512-444-4479)

environmental cataloging of extensive biological and other data for Texas; includes distribution records by county for all species of organisms reported from Texas

Fayne Tucker, Air Pollution Control Officer, Lake County Offices, Lakeport, California 95453

viewpoint of geothermal operations from other than industry

U.S. Fish and Wildlife Service Area Office, Jerry Bently, 300 E. 8th, Room G-121, Austin, Texas 78701 (512-397-5434)

U.S. Fish and Wildlife Service Office of Endangered Species, Carol Justice, Jack Woody, P.O. Box 1306, Albuquerque, New Mexico 87103 (505-766-3974)

U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, Virginia 22092

publications of U.S. Geological Survey on geothermal and other topics

University of Texas Libraries, James Thornborough, Documents Collection, Austin, Texas 78712 (512-471-7516)

federal documents in University of Texas Library system

University of Texas Libraries, Perry-Castaneda Library, (512-471-5553) Circulation Services, borrowers cards (Interlibrary Borrowing), Austin, Texas 78712 (512-471-3976)

Stephen R. Vehrs, Refuge Manager, Salton Sea National Wildlife Refuge, P.O. Box 247, Calipatria, California 92233

management of Salton Sea Refuge near geothermal operations in California's Imperial Valley

Richard (Dick) Wade, U.S. Fish and Wildlife Service, P.O. Box 1306, Albuquerque, New Mexico 87103 (505-766-2091)

J.D. (Don) Walker, Production Department, Gulf Oil Corporation, Vaughn Building, Austin, Texas (512-476-7824)

oil production by Gulf Oil Corp. in the Texas coastal zone

Ray Wallace, U.S. Geological Survey, Bay St. Louis, Mississippi 39520

geochemistry of geopressured water

Geraldine Watson, Route 2, Box 1402, Silsble, Texas 77656 (712-727-2355), Big Thicket National Preserve, National Park Service, Beaumont, Texas (712-838-0271)

ecology of the Big Thicket Region of east Texas; impacts of the forestry and oil industries in east Texas

Carl Weinberg, Pacific Gas and Electric Company, 3400 Crow Canyon
Road, San Ramon, California 94106 (415-820-2000)

environmental research on geothermal steam operations in the Geysers field, California

Bill White, Bureau of Economic Geology, University of Texas, P.O. Box
X, Austin, Texas 78712 (512-471-1534)

geological and environmental aspects of geopressured-geothermal energy

Donald White, U.S. Geological Survey, 345 Middlefield Road, Menlo Park,
California 94025 (415-323-8111)

U.S. Geological Survey geothermal activities

Robert Wheeler, Department of Geology, Lamar University, Beaumont,
Texas (713-838-8913 TEXAN 855-8913)

petroleum geology of east Texas

R. H. Whittaker, Dept. of Ecology and Systematics, Cornell University,
Ithaca, New York (607-256-4747)

community ecology and productivity

Bert Wilkins, Louisiana State University, Baton Rouge, Louisiana 70803

salt dome oil storage

Dan Wilkinson, L.G.L. Limited, 103A Pleasant St., Bryan, Texas
77801

contractor for U.S. Bureau of Reclamation studies of rare plants in the Choke Canyon Reservoir project

D. L. (Mike) Williams, Submanager of Crude Oil Department, Marketing,
Gulf Oil Corporation, Houston, Texas (713-226-1011)

Wirth Associates, 2701 East Thomas Road, Phoenix, Arizona 85016,
(602-956-9830)

consulting services for MEPA required projects

P. A. Witherspoon, Lawrence Berkely Laboratories, Berkeley,
California 94700 (415-843-2740 Ext. 5082)

see Narasimhan for specialties

Donald E. Wohlschlag, University of Texas Marine Science Institute,
Port Aransas Marine Laboratory, Port Aransas, Texas 78373
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impacts of geopressured activities on marine ecosystems; marine ecophysiology; effects of sublethal stresses on fishes

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wilderness regions of the U.S.; field observations of the Ivory-Billed Woodpecker